LABORATORY EXPERIMENTS IN GENERAL CHEMISTRY

H·B·NORTH

D. VAN NOSTRAND COMPANY

Edmund O'Neill

Laboratory Experiments in General Chemistry

BY

H. B. NORTH, PH.G., D.SC.

Associate Professor of Chemistry in Rutgers College
Member of the American Chemical Society
American Electrochemical Society
Société chimique de France

36 ILLUSTRATIONS

NEW YORK
D. VAN NOSTRAND COMPANY
25 PARK PLACE
1913

Stanhope Press
F. H. GILSON COMPANY
BOSTON, U.S.A.

PREFACE.

THIS manual is designed to cover a laboratory course in General Chemistry given in connection with a series of experimental lectures. It contains five hundred carefully chosen experiments on the more common elements and is so arranged that it can be used in connection with any good text-book. The work includes a large number of experiments similar to those found in other manuals and, in addition, numerous more advanced experiments which, to the author's knowledge, have never before appeared in a laboratory manual in General Chemistry.

It is not supposed that any one student will perform all of these experiments. The reason for the large number is rather that experiments may be chosen to meet the needs of the various classes of students. In the author's laboratory an assignment of experiments for each laboratory period is posted on the bulletin board. A number of the simpler experiments are selected for the beginners while the more advanced and consequently more difficult exercises are assigned to those who have had previous chemical training. In order to better facilitate this method of assignment, all experiments have been numbered consecutively.

In writing this book, the author has attempted to word each and every experiment in such a way as to

make it impossible for the student to mistake the exact meaning. A preliminary edition of the work has been in use in the author's laboratory for one year and has proved most satisfactory.

H. B. N.

New Brunswick, N. J.,
Aug. 1, 1913.

CONTENTS.

LABORATORY EXPERIMENTS IN GENERAL CHEMISTRY

CHAPTER I.

CHEMICAL CHANGES AND THE AGENCIES WHICH PRODUCE THEM.

1. Carefully weigh a small porcelain evaporating dish; then weigh into it exactly 5 gms. of powdered iron. Place the dish on a ring stand and heat strongly for about 10 minutes. Allow to cool; then re-weigh.

Compare the weights of the iron. Has the iron increased or decreased in weight? How much? What is the reason for this change? Through what agency has this change been brought about?

2. To a few cubic centimeters of a solution of sodium chloride ($NaCl$) in a test tube add a little silver nitrate ($AgNO_3$) solution. Observe that the compound formed is pure white in color.

Allow the test tube containing the white precipitate to stand on the desk for an hour, or until the end of the laboratory period. If convenient, place it in the direct rays of the sun. Has any change in appearance taken place? If so, what has caused this change?

3. Introduce a little powdered sodium bicarbonate ($NaHCO_3$) into a test tube and treat with water. In another tube treat some potassium acid tartrate

($KHC_4H_4O_6$) with water. Have any changes taken place? If so, are they physical or chemical changes?

In a dry porcelain mortar rub together about equal portions of sodium bicarbonate and potassium acid tartrate. Do you notice any change? Now place the mixture in a dry beaker and add water. What phenomenon do you observe? What agency is the cause of this change?

Summary. What is the difference between a physical and a chemical change? In what does the study of chemistry differ from that of physics? Mention several physical changes and several chemical changes.

What three agencies of chemical change have been studied in the preceding experiments? Mention another important agency of chemical change.

Mention some of the phenomena which indicate chemical change.

CHAPTER II.

HYDROGEN (H; 1).

4. **Preparation.** Place a small piece of zinc (Zn) in a test tube and add a few cubic centimeters of dilute hydrochloric acid (HCl). What happens? Bring the mouth of the test tube to a flame. What happens?

In like manner try the action of hydrochloric acid on small pieces of magnesium (Mg), iron (Fe) and aluminum (Al). Try the action of dilute sulphuric acid (H_2SO_4) on zinc, magnesium, iron and aluminum. Heat gently if necessary.

Can you make a general statement covering all these cases?

5. Carefully dry a small piece of metallic sodium (Na) and wrap it in a piece of dry filter paper. Fill a test tube with water and invert it in a dish of water, holding the mouth of the tube under the surface. By means of pincers quickly introduce the piece of sodium wrapped in paper into the mouth of the test tube under the water. What do you observe? Test the gas formed.

6. Place a few small pieces of metallic aluminum in a test tube and add a few cubic centimeters of a strong solution of potassium hydroxide (KOH) or sodium hydroxide (NaOH). Heat in the Bunsen flame. Explain the action.

Repeat the experiment, using metallic zinc instead of aluminum.

7. Arrange an apparatus as shown in Fig. 1. The flask contains 100 cc. of water and a few pieces of broken tile or pumice to prevent "bumping." The iron tube should be partially filled with iron filings. Make all connections tight.

Heat the iron pipe strongly and at the same time boil the water in the flask. When the air has been driven from the apparatus, place an inverted test tube filled with water over the end of the delivery tube. What gas

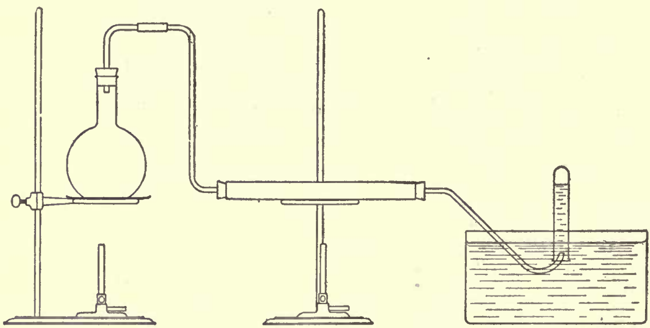


FIG. 1.

collects in the test tube? Test it by bringing to a flame. How have the iron filings changed in appearance?

8. Properties. Arrange a hydrogen generator as shown in Fig. 2, and at the same time prepare the tubes necessary in Exps. 11 and 12. (The apparatus must be submitted to the approval of the instructor before going on with the experiment.) Place 25 gms. of zinc (Zn) in the flask; add enough water to barely cover the metal. Now add concentrated hydrochloric acid (HCl) through the thistle tube, a little at a time, until a brisk effervescence takes place. (CAUTION! *Never bring a flame near a hydrogen generator.*)

To test the gas, collect a test tube full over water and then quickly bring the mouth of the test tube to a flame. If an explosion follows, the hydrogen is impure. If the hydrogen is pure, it will burn quietly. Test the gas at intervals until it is found to be pure. Before making a test, be sure that there is no hydrogen burning in the test tube.

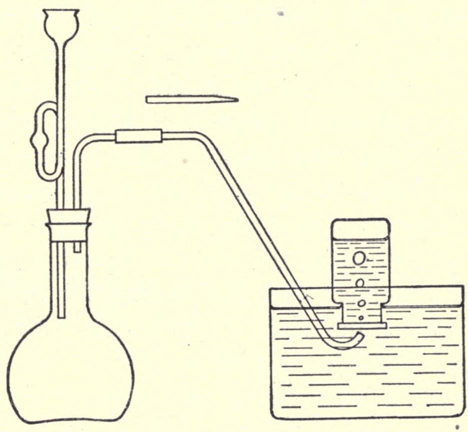


FIG. 2.

When the gas has been ascertained to be pure, collect several bottles over water in the manner shown in the drawing. These bottles of gas are to be used in the following experiments.

9. Why is hydrogen always kept in inverted bottles? Pour hydrogen upward into an empty bottle. Then test both bottles to see if they contain any of the gas.

What is meant by the term "vapor density"? What is the standard of vapor density? What is the vapor density of air?

10. Thrust a burning splinter upward into an inverted bottle of hydrogen. Is the flame extinguished? Does the hydrogen burn at the mouth of the bottle? Carefully withdraw the splinter so that it will ignite again. Repeat several times.

Does hydrogen support combustion? What do you understand by the term "combustion"?

11. Remove the delivery tube from the hydrogen generator and in its place insert a short piece of tubing drawn to a point at the outer end. Add a little more HCl to the generator if necessary. Wrap a towel about the generator and then ignite the gas issuing from the glass tip. Notice the color of the flame **immediately.** (After burning some time, the flame will become yellow, due to the sodium in the glass.) Invert a clean dry beaker for a moment over the burning jet of hydrogen. What collects on the inside of the beaker? What is the product of combustion of hydrogen?

12. Attach a wash bottle and delivery tube to the generator as shown in Fig. 3. Add 2 or 3 cc. of potassium permanganate ($KMnO_4$) solution to a beaker half full of water. By means of the delivery tube, pass hydrogen through the solution. Do you notice any change?

Remove the hydrogen generator. Then generate hydrogen in the beaker containing the solution by dropping in a few pieces of zinc (Zn) and then adding a few cubic centimeters of concentrated sulphuric acid (H_2SO_4). If no gas is generated, add more acid. Allow to stand for several minutes. What change takes place? Why does hydrogen cause a change in this case and not in the previous one?

Repeat using a solution of potassium dichromate ($K_2Cr_2O_7$) instead of potassium permanganate. Describe the results.

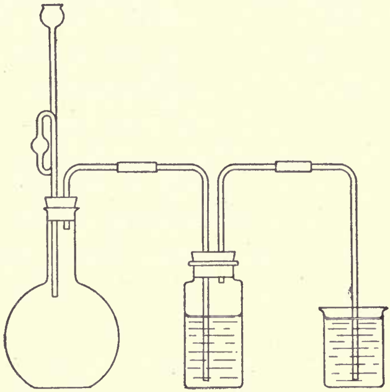


FIG. 3.

13. Other Product of the Action of an Acid on a Metal. Filter the solution formed in the hydrogen generator and carefully evaporate the clear solution to dryness in a porcelain evaporating dish. Describe the nature of the material left in the dish. (Hood.)

Summary. What four general methods for the production of hydrogen have been studied? Mention one other good method for the preparation of this gas.

For what is hydrogen taken as the standard and why is it so taken? What is meant by molecular hydrogen and by nascent hydrogen? Does the latter differ from the former in chemical properties? If so, which is the more active?

Problems.* (a) To prepare 30 gms. of hydrogen by the action of HCl on zinc, what weight of zinc is necessary? What is the volume of the 30 gms. of hydrogen?

* See "Chemical Arithmetic," Appendix, page 186.

(b) How many liters of hydrogen can be produced by the action of an excess of H_2SO_4 on 215 gms. of metallic zinc?

(c) If equal weights of zinc, aluminum, iron and magnesium are dissolved in HCl, which will produce the greatest amount of hydrogen?

Reduction by Hydrogen.

(Quantitative.)

14. Arrange an apparatus consisting of a hydrogen generator, wash bottle, calcium chloride tube (*a*), hard glass tube (*b*) and a second calcium chloride tube (*c*), as shown in Fig. 4. Both of the calcium chloride tubes

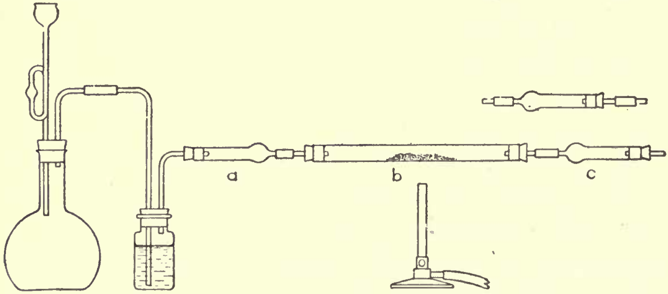


Fig. 4.

should be filled with dry granulated calcium chloride, $CaCl_2$. Prepare caps for the ends of *c* as shown in the drawing so that this tube may be weighed without danger of its contents absorbing moisture from the air. The caps can be conveniently made of 1-inch pieces of small rubber tubing, one end being plugged with a short piece of glass rod.

Thoroughly clean the hard glass tube and then weigh it accurately. Now introduce about 5 gms. of ferric oxide (Fe_2O_3)* into the tube as near the center as pos-

* Cupric oxide, CuO, may be substituted for Fe_2O_3.

sible, and again weigh. The difference in the two weighings represents the amount of Fe_2O_3 taken.

Cap the ends of *c* and weigh accurately. Then connect the apparatus as shown in the drawing, first, however, introducing about 30 gms. of zinc into the flask. Through the thistle tube add enough water to cover the zinc and then sufficient concentrated HCl to produce a brisk evolution of hydrogen. Wrap a towel about the generator and then test the gas being evolved from the apparatus. To do this, hold an inverted test tube over the end of *c* from which gas is issuing, thus collecting the test tube full of hydrogen by displacement of air; then quickly bring the mouth of the test tube to a flame. If the gas is pure it will burn quietly. When the hydrogen coming from the exit tube is pure, apply heat to the middle of the hard glass tube by means of a Bunsen burner.

The hydrogen, coming from the generator, is freed from HCl fumes by the wash bottle of water, and is then dried by the calcium chloride tube *a*. The Fe_2O_3 heated in the dry hydrogen is reduced by the latter to Fe, the other product of the reaction, water (H_2O), being absorbed in the calcium chloride tube *c*. Care must be taken to volatilize and drive into *c* any water which condenses in the end of the hard glass tube *b*.

After heating about 15 minutes, take away the flame and allow the hard glass tube and contents to cool, the current of hydrogen being continued, however. When the tube is thoroughly cooled, disconnect the apparatus and quickly cap the ends of *c*. Then carefully weigh *b* and also *c*.

What has been the decrease in the weight of the Fe_2O_3?

What does this loss represent? What is the increase in the weight of *c*? What does this increase represent? From the loss in weight of the Fe_2O_3, calculate what should have been the increase in the weight of *c*, and compare this figure with that found experimentally. What is the percentage error? Was the Fe_2O_3 in *b* completely reduced? If not, what per cent of the Fe_2O_3 was not reduced?

Arrange all data in tabular form

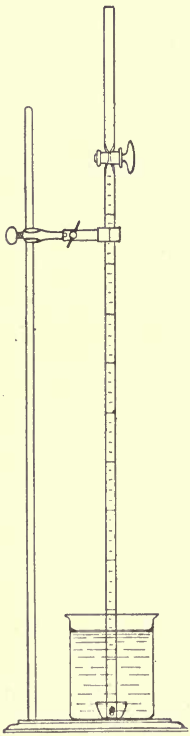


FIG. 5.

DETERMINATION OF THE EQUIVALENT WEIGHT OF MAGNESIUM.

(Quantitative.)

15. **First Method. By Means of the Eudiometer.** Accurately weigh out 0.03 gm. of magnesium (Mg) ribbon and introduce it into a porcelain crucible. Fill the crucible with water and lower it into a beaker likewise filled with water. Now fill the long arm of the eudiometer with water and by covering the end with the finger, invert the tube in the beaker of water and clamp in position as shown in Fig. 5. The tube should entirely cover the metal in the crucible and should be completely filled with water below the stopcock.

Partially fill the upper end of the eudiometer with concentrated HCl. Now carefully open the stopcock to allow a few cubic centimeters of the acid to run down into the water. On

account of its greater specific gravity, the acid gradually settles to the bottom of the tube and comes into contact with the magnesium. The action is slow at first but gradually increases. Care must be exercised to prevent the introduction of too much acid.

When the metal is entirely dissolved, close the end of the tube under the water by means of the finger and transfer the tube to a tall cylinder filled with water. Raise the tube so that the surface of the water within is at the same level as the water in the cylinder, and then carefully read the volume of gas in the eudiometer. Also take the temperature of the water and note the barometric pressure in the room. The observed pressure is not exactly the same as the pressure within the tube, on account of the water vapor in the latter. The difference in pressure is equal to the aqueous tension at the observed temperature.

The volume of gas must now be corrected to standard conditions, that is, to 0° C. and 760 mm. pressure. Let:

T = observed temperature,
T' = 0° C. (273° Ab.),
P = observed pressure,
a = aqueous tension at T,
$P - a$ = actual pressure in the tube,
P' = 760 mm.,
V = observed volume,
V_0 = volume corrected to 0° and 760 mm.

According to the laws of Charles and Boyle,*

$$V_0 = \frac{VPT'}{P'T},$$

* See Appendix, page 181.

but, inasmuch as the actual pressure within the tube is not P but is $P - a$, the expression becomes:

$$V_0 = \frac{V(P-a)T'}{P'T}.$$

The weight of 1 liter (1000 cc.) of hydrogen at standard conditions is 0.0899 gm.; hence the weight of 1 cc. is 0.0000899 gm., and the weight of V_0 cc. may be expressed by the formula:

$$V_0 \times 0.0000899 \text{ gm.}$$

The equivalent weight of magnesium is the weight of that metal which is equivalent to 1 gm. of hydrogen. Inasmuch as 0.03 gm. of magnesium is equivalent to $V_0 \times 0.0000899$ gm. of hydrogen, the amount equivalent to 1 gm. of the latter is found by the proportion:

$$(V_0 \times 0.0000899) : 0.03 :: 1 : x,$$

in which x equals the equivalent weight of magnesium.

16. Repeat the above experiment, using aluminum (Al) or zinc (Zn) instead of magnesium. When performing the experiment with zinc, employ 0.1 gm. of the metal instead of 0.03 gm. as directed above. Why?

Compare the equivalent weights of the metals determined with their respective atomic weights. Does this comparison bring out any noteworthy facts? What can you judge as to the valence of the metals?

17. Second Method. Without Special Apparatus. This method is much more crude than that described in Exp. 15, but inasmuch as the volume of gas liberated is large, the relative error is small, hence the method yields fairly accurate results.

Prepare an apparatus as shown in Fig. 2, page 5.

Accurately weigh out about 5 gms. of pure zinc and introduce it into the flask. Through the thistle tube add sufficient water to cover the zinc. Place an inverted bottle filled with water over the end of the exit tube and have several other bottles filled with water ready to substitute for the first as soon as it is filled with gas.

Now add through the thistle tube a measured volume of concentrated HCl, 10–20 cc. If this does not produce a brisk evolution of hydrogen, add more acid, being careful to note the exact volume. Collect all the gas coming from the exit tube and use care to prevent loss of gas while changing the bottles.

When the zinc is entirely dissolved, ascertain the total volume of gas which has been collected. The volume of each bottle can readily be found by filling the bottle with water and then measuring the latter by means of a graduated cylinder. The total volume of gas collected differs from the exact volume of hydrogen liberated only by the volume of the concentrated HCl employed. The volume of hydrogen generated, V, is found, therefore, by subtracting the volume of concentrated HCl used from the total volume of gas collected.

Read the barometer and take the temperature of the water over which the gas was collected. The volume of hydrogen must now be reduced to standard conditions. Ignoring the aqueous tension, and making use of the formula given in Exp. 15, we have

$$V_0 = \frac{VPT'}{P'T},$$

and the weight of the hydrogen equals

$$V_0 \times 0.0000899 \text{ gm.}$$

The equivalent weight of zinc is then obtained by the following proportion:

$$(V_0 \times 0.0000899) : Wt. :: 1 : x,$$

in which *Wt.* is the weight of zinc used, and *x* is the equivalent weight of the metal.

CHAPTER III.

OXYGEN AND OZONE.

OXYGEN (O; 16).

18. Preparation. In hard glass test tubes heat separately small amounts of each of the following substances: mercuric oxide (HgO), barium peroxide (BaO_2), potassium chlorate ($KClO_3$), potassium dichromate ($K_2Cr_2O_7$),

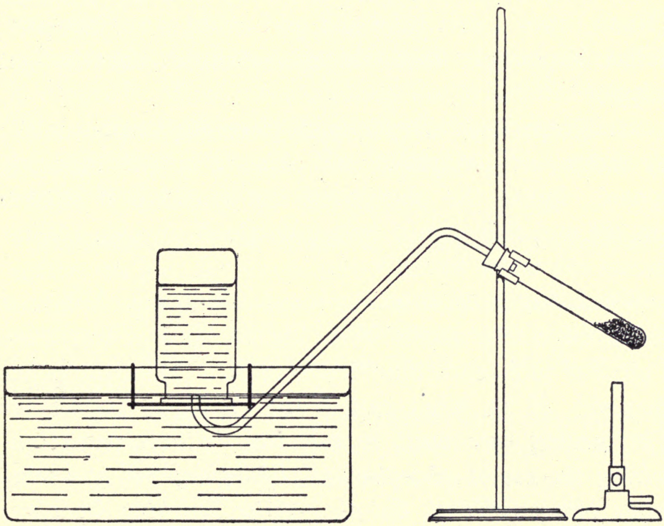


FIG. 6.

potassium nitrate (KNO_3). In each case test the gas evolved by introducing a glowing splinter into the mouth of the tube.

19. Mix about 10 gms. of manganese dioxide (MnO_2) and 10 gms. of potassium chlorate ($KClO_3$). Arrange

an apparatus as shown in Fig. 6, and introduce the mixture of MnO_2 and $KClO_3$ into the test tube. Apply heat very slowly and gradually. After a regular flow of oxygen comes from the apparatus, collect several bottles of the gas by displacement of water. (These bottles of oxygen are for use in the following experiments on the properties of the element.)

What reaction has taken place in the above preparation of oxygen? Why is the MnO_2 mixed with the $KClO_3$?

20. Introduce about 2 gms. of sodium peroxide (Na_2O_2) into a test tube and add about 5 cc. of water. What happens? Test the gas evolved. Is the gas oxygen?

21. Properties. Dry a small piece of phosphorus (P) by means of filter paper and place it in a deflagrating spoon. Ignite the phosphorus by touching it with a hot file and then thrust into a bottle of oxygen. What causes the white fumes?

When the phosphorus has stopped burning, withdraw the deflagrating spoon from the bottle and introduce a piece of moistened blue litmus paper. Does the paper change? If so, what causes the change? (CAUTION! *The greatest care must be exercised in experiments involving the use of phosphorus. Phosphorus is spontaneously inflammable in the air. After finishing the above experiment the iron deflagrating spoon should be strongly ignited in the Bunsen burner flame to burn any remaining traces of phosphorus. Never handle phosphorus with the fingers; the heat of the hand is sufficient to cause it to ignite. Phosphorus burns are very painful.*)

22. Fill a deflagrating spoon with flowers of sulphur (S). Ignite in the Bunsen flame and quickly introduce

into a bottle of oxygen. When combustion is complete, withdraw the deflagrating spoon and hold a strip of wet blue litmus paper in the mouth of the bottle. Explain fully what produces the change in the litmus paper.

23. Unravel one end of a piece of picture wire for about 1 cm. Heat the unravelled end to redness and quickly plunge into a bottle of oxygen. Notice the brilliancy of the combustion. What are the metallic looking globules formed? Introduce a piece of moistened litmus paper into the mouth of the bottle. Is the paper changed?

Summary. In what respects does oxygen differ from hydrogen? What test would you use to identify oxygen? Why does a splinter burn more readily in oxygen than in air? Should oxygen, like hydrogen, be kept in inverted bottles? Why?

Problems. (a) What volume of oxygen can be prepared by igniting 200 gms. of mercuric oxide?

(b) The gas chamber in a gasometer is 40 cm. in diameter and 90 cm. high. What weight of a mixture of equal parts of MnO_2 and $KClO_3$ will be necessary to generate enough oxygen to fill the gasometer?

(c) What weight and volume of oxygen can be obtained by the complete electrolysis of 1 liter of water? What weight and volume of hydrogen will be produced at the same time?

Determination of the Weight of a Liter of Oxygen.

(Quantitative.)

24. Arrange the apparatus shown in Fig. 7. The bottle should be of about 2 liters capacity; all stoppers should be of rubber. Completely fill the bottle *a* with water; insert the stopper carrying the two glass tubes

as shown. Water will be forced up through tube *b* completely filling it. Now clamp this tube by means of a pinchcock as shown. Insert tube *b* in beaker *c* which should be empty.

Remove the test tube *d* and fill it about one third full of a mixture of equal parts of $KClO_3$ and MnO_2, both of which have been previously dried by gently warming

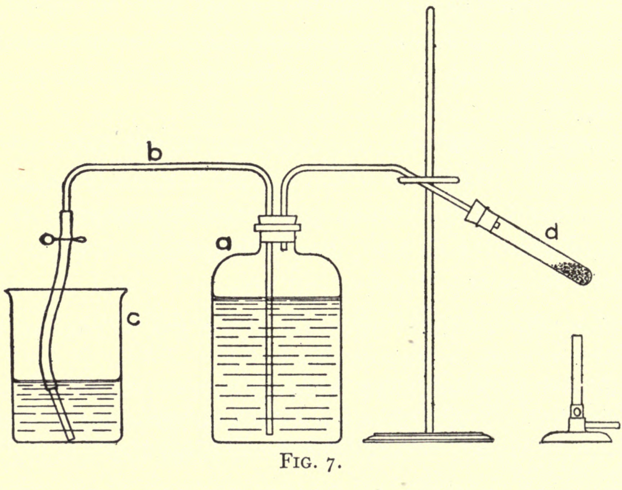


FIG. 7.

in a porcelain evaporating dish. Weigh the tube with the mixture and let w' represent this weight. Connect the test tube with the apparatus, and then open the pinchcock on *b*. If all connections are tight, no water will run into *c*.

Apply heat slowly and gently to the end of the test tube containing the mixture of $KClO_3$ and MnO_2. If too strong a heat is applied, oxygen will be evolved too rapidly and may result in loss. The gas should be evolved slowly and steadily. The oxygen which col-

lects in bottle *a* displaces its own volume of water, forcing it over into beaker *c*.

The heating is continued until bottle *a* is about half full of oxygen. Then remove the source of heat and allow the apparatus to cool. When cool, raise beaker *c* until the surface of the water contained therein and the surface of the water in *a* are at the same level. While holding the beaker in this position, tighten the pinchcock on tube *b* and then remove the latter from *c*.

Measure the volume of the water in *c*. This is the same as the volume of oxygen in *a*. Take the temperature of the water in *c*; the oxygen in *a* is at the same temperature. Note barometric pressure in the room.

Carefully remove the test tube *d* from its stopper and weigh accurately. Let this weight be represented by w''. Then $w' - w''$ equals the weight of the oxygen evolved.

The volume, V, must now be corrected for temperature and pressure. This is done in exactly the same manner as described in Exp. 15, by the formula:

$$V_0 = \frac{V(P - a)T'}{P'T}.$$

If V_0 cc. of oxygen under standard conditions of temperature and pressure weigh $w' - w''$ gms., the weight of 1 liter (1000 cc.) of oxygen can be obtained from the proportion:

$$V_0 : (w' - w'') :: 1000 : x,$$

in which x equals the weight of a liter of oxygen at the standard conditions of temperature and pressure.

Calculate the theoretical weight of a liter of oxygen

and compare with the result obtained experimentally. What is the percentage error? To what do you attribute the error?

In this experiment is it necessary to drive all the available oxygen from the mixture in the tube? Why?

Verification of the Law of Definite Proportions.

25. **Part I.** Carefully weigh a clean, dry porcelain crucible and cover. By means of fine sand-paper thoroughly clean a piece of magnesium ribbon about 3 feet long. Wipe the ribbon with a towel to remove particles of dust. Twist the ribbon into a coil and press down firmly into the crucible. Replace the cover and again weigh. The difference in the two weighings is the weight of magnesium taken.

Place the crucible on a pipestem triangle on a ring stand and heat gently with a small flame. The burner should be held in the hand. With the other hand, by means of a pair of clean crucible tongs or steel pincers, hold the cover of the crucible a little above the crucible in order that air may enter the latter. If the magnesium ribbon takes fire, instantly cover the crucible and withdraw the flame until the burning within the crucible ceases. Then again apply heat, holding the crucible cover as before. Great care must be taken to prevent loss of any of the white powder which clings to the under side of the cover.

When oxidation seems to be complete, that is, when the magnesium ribbon no longer takes fire, entirely remove the cover, being careful to lose none of the white

oxide which clings thereto. Place the crucible in an inclined position on the triangle and heat strongly for a few minutes. Then allow the crucible to cool, replace the cover and again weigh.

In order to make sure that oxidation is complete, the crucible without the cover should again be placed in an inclined position on the triangle and strongly heated for a few minutes. Allow to cool; cover and weigh. The two successive weighings should be identical.

What is the weight of the contents of the crucible? How much has the magnesium gained in weight? Calculate the percentage gain in weight.

Part II. Carefully weigh a small clean porcelain evaporating dish. Clean about 3 feet of magnesium ribbon as described in Part I, twist into a coil, introduce into the dish and carefully weigh. The difference in the two weighings equals the amount of magnesium taken.

To the contents of the dish add enough distilled water to cover the magnesium. Then add pure concentrated HNO_3, a few drops at a time, quickly covering the dish with a watch glass after each addition. (Why?) When the metal is entirely dissolved, place the dish on a water bath and evaporate to dryness. Transfer the dish to a triangle on a ring stand and apply heat, very carefully at first, to prevent loss, and then more strongly until brown fumes are no longer evolved. Allow the dish to cool and then weigh.

How much has the magnesium gained in weight? What is its percentage gain in weight?

Compare the percentage gain in weight found in Part II with that found in Part I. What conclusion can you draw from these two experiments?

OZONE.

26. In a good-sized beaker place a few pieces of yellow phosphorus. (CAUTION! *See page 16.*) Add enough water to partially cover the phosphorus. Cover the beaker with a watch glass and allow to stand for about 10 minutes.

Remove the watch glass and notice the odor of the air in the beaker. Test the air for ozone by introducing a piece of filter paper moistened with starch paste containing a little potassium iodide (KI). What do you notice? Explain all the chemical changes which have taken place in the test solution.

27. Pour a few drops of ether into a beaker or a wide mouth bottle and quickly cover. (CAUTION! *Ether is very inflammable and should never be poured from a bottle when a flame is near.*) Keeping the bottle tightly covered, shake it to completely cover the sides with a film of ether.

Heat the end of a glass rod almost to redness and plunge it into the bottle. If the rod is too hot, an explosion will occur. Test the atmosphere in the beaker with filter paper saturated with the KI-starch paste test solution. Also note the odor coming from the bottle.

Summary. How can ozone be prepared in larger quantities? Does ozone ever occur in the air? To what cause may this be due? Does oxygen affect KI-starch paste? Why should ozone be more active than oxygen? Mention one other good test for ozone.

CHAPTER IV.

WATER AND HYDROGEN PEROXIDE.

WATER.

28. Distilled Water. Arrange an apparatus consisting of a condenser and a distilling flask fitted with a ther-

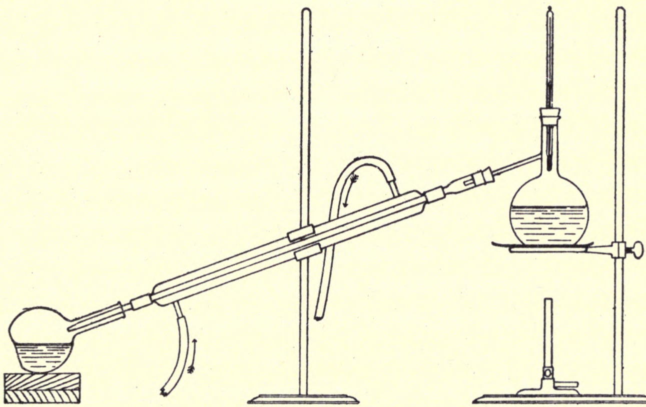


FIG. 8.

mometer as shown in Fig. 8. Partially fill the flask with water and heat to boiling. Collect the distilled water which runs from the condenser. Continue the distillation until about 150 cc. are obtained. Notice the temperature during distillation.

What is meant by distillation? Why is distilled water purer than the ordinary city service water?

29. On a clean watch glass evaporate to dryness a few cubic centimeters of the ordinary city service water, or, better still, a few cubic centimeters of river water.

Notice the amount of residue. (In making this evaporation, place the watch glass on a wire gauze on a ring stand and heat gently by means of a small flame.) On a second watch glass evaporate a similar volume of distilled water and compare the amount of residue with that previously obtained. What is your deduction as to the relative purity of the two samples of water?

Solubility in Water.

30. Solids. Test the solubility of a number of salts and arrange the results in two columns headed respectively "Soluble" and "Insoluble."

To make a solubility test, introduce a small piece of the material to be tested, not larger than a grain of wheat, into a test tube half full of distilled water. Close the tube with the thumb and shake vigorously. If the substance does not seem to dissolve, heat to boiling for a few moments and then allow the tube to stand several minutes.

Any of the following substances may be used in this experiment: copper sulphate ($CuSO_4$), ferrous sulphate ($FeSO_4$), mercurous chloride ($HgCl$), potassium dichromate ($K_2Cr_2O_7$), potassium chloride (KCl), calcium carbonate ($CaCO_3$), magnesium sulphate ($MgSO_4$), borax ($Na_2B_4O_7$) and ammonium chloride (NH_4Cl).

Compare the results obtained with the table of solubilities on page 200. Are there any discrepancies? If so, to what are the discrepancies due?

31. Liquids. Test the solubility of several liquids in water by adding about 3 cc. of each to a test tube half full of distilled water. In each case if the liquid does not dissolve immediately, shake the tube gently

and then allow to stand for a moment. Arrange the data obtained as in the previous experiment.

The following compounds, which are liquids, may be used in this experiment: ether, alcohol, kerosene, chloroform, glycerine and carbon disulphide.

Determination of the Solubility of Sodium Chloride.

(Quantitative.)

32. Make a saturated solution of sodium chloride ($NaCl$) by treating about 100 gms. of the salt with 200 cc. of water in a small flask. Allow to stand, with occasional shaking, for about half an hour. While the mixture is standing, accurately weigh a small porcelain evaporating dish.

When the solution is saturated, i.e., when no more salt will dissolve, filter a portion of the solution through a plaited filter, catching the filtrate in the evaporating dish. The dish should be about half full of the solution. Take the temperature of the solution in the dish. Carefully weigh dish and solution and deduct the weight of the empty dish, thus arriving at the exact weight of the salt solution. Let this weight be represented by w'.

Evaporate the solution on a water bath, allowing the dish to remain on the bath until the salt is perfectly dry. When cool, again weigh dish and contents. Subtract the weight of the empty dish in order to find the exact weight of the residue — sodium chloride. Represent the weight of sodium chloride by w''.

The actual weight of the water in which the w'' grams of salt were dissolved is equal to $w' - w''$. The

solubility of a substance at any given temperature is the number of grams of the substance that will dissolve in 100 gms. of water at that temperature. If w'' grams of salt will dissolve in $w' - w''$ grams of water at temperature t, the number of grams that will dissolve in 100 gms. of water at that temperature can be calculated by the proportion:

$$(w' - w'') : w'' :: 100 : x,$$

in which x equals the solubility of sodium chloride at temperature t.

Compare the result obtained with a table of the solubility of sodium chloride and report the percentage error. Draw a curve representing the solubility of sodium chloride from 0° to 100° C.

Examination of Water for Impurities.

(Qualitative.)

33. Each of the following tests should be made with distilled water and with samples of several other waters from as widely differing sources as possible. City service, river, canal, ocean, lake, well or rain water may be used. Chemically pure reagents must be used in making these tests. Compare the results obtained in each test.

Lime. To each of the samples of water in test tubes, add a few drops of ammonium hydroxide and a few drops of ammonium oxalate ($(NH_4)_2C_2O_4$). Heat each tube to boiling and then allow to stand and settle. The precipitate of calcium oxalate (CaC_2O_4) shows the presence of calcium salts in the water. Calcium salts are always reported as lime.

Sulphates. Test the several samples of water for sulphates by adding to each a drop of HCl and a few drops

of barium chloride ($BaCl_2$) solution. Heat to boiling and then allow to stand and settle. The white precipitate is barium sulphate, $BaSO_4$.

Chlorides. Make the test for chlorides by adding to each sample a drop of HNO_3 and a few drops of silver nitrate ($AgNO_3$) solution.

Ammonia. The test solution for ammonia is Nessler's reagent, which is a mixture of potassium mercuric iodide ($HgI_2.2\ KI$) and potassium hydroxide (KOH) solutions. With waters containing ammonia or ammonium salts, the reagent produces a yellowish brown color, the depth of color being indicative of the amount of ammonia present. The color can be most easily judged by looking down through the tube at a piece of white paper.

Test the several samples of water for ammonia by adding to equal volumes of each 1 cc. of Nessler's reagent. Allow the tubes to stand for two or three minutes before making the comparison.

34. **Hardness of Water.** Add about 5 cc. of soap solution to 100 cc. of distilled water in a clean 500 cc. flask. Shake the flask for several minutes, and notice the sound which is produced. Does a permanent lather form? The formation of a lather and the production of very little noise when the flask is shaken indicate that the water is soft.

Test the hardness of several other samples of water by adding a little soap solution to 100 cc. of each as described above. Record all results.

35. Repeat the test with one of the samples of hard water, using, instead of 5 cc. of the soap solution, at least 10 or 15 cc. Shake as before. Do you get the same results as with this water in Exp. 34? What is

the reason? What can be added to a hard water to make it soft?

36. Repeat the experiment with distilled water and 5 cc. of soap solution, first, however, adding to the distilled water 10 or 15 cc. of a solution of any calcium or magnesium salt. Compare with the results obtained from Exp. 34.

What has caused the change? Is the water now hard or soft? If it is hard, how can it be softened?

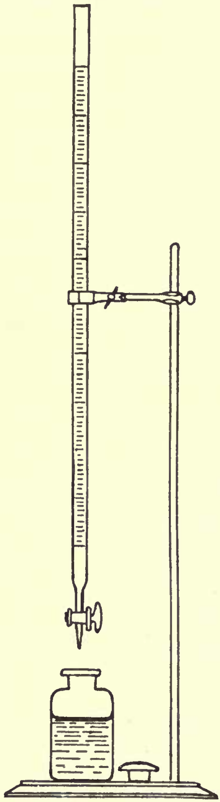


Fig. 9.

Determination of the Hardness of Water.

(Quantitative.)

37. Obtain a supply (about 50 cc.) of "standard soap solution" from the stock bottle on the reagent shelves. Rinse out a burette three times with small amounts of the soap solution and then fill the burette with it (Fig. 9).

Into a clean glass-stoppered bottle introduce exactly 100 cc. of the ordinary city service water. Note the level of the solution in the burette, then allow the solution to run, a drop at a time, into the bottle of water, shaking the bottle vigorously after each addition. Continue to add soap solution in this way until a drop finally produces a permanent lather. Read the burette again and note the number of cubic

centimeters of soap solution required to produce the lather, i.e., to discharge the hardness of the water. The standard soap solution is so made up that 1 cc. is equivalent to 1 part of calcium carbonate, i.e., hardness, in 100,000 parts of water. Express your results in parts of hardness per 100,000.

This experiment should be repeated two or three times and the results averaged. All results, however, should appear in the report.

In a similar manner determine the hardness of one or two other samples of water, as river water, or well water.

38. **Water of Crystallization.** Notice the color of crystals of copper sulphate ($CuSO_4$). Powder several crystals and notice the color of the powder. Introduce about 10 gms. of the powder into a porcelain evaporating dish and heat gently until the powder is white. What kind of a change has taken place? Allow the dish and powder to cool; then add a few cubic centimeters of water. Notice the immediate change in appearance. Explain all changes.

39. Place a crystal of copper sulphate in a test tube and apply heat. Observe that the water driven out of the crystal condenses at the outer end of the tube. In like manner, in separate test tubes, heat crystals of the following substances: magnesium sulphate ($MgSO_4$), potassium dichromate ($K_2Cr_2O_7$), potassium chloride (KCl), ferrous sulphate ($FeSO_4$) and borax ($Na_2B_4O_7$). Judging by the amount of water in each case, which of these salts do you conclude contain water of crystallization?

Compare the results of this experiment with those obtained in Exp. 30. Do you conclude that all salts

having water of crystallization are soluble in water? Do you conclude that all salts having no water of crystallization are insoluble?

40. Obtain about one third of a test tube full of sodium acetate ($NaC_2H_3O_2$) from the reagent bottle. Add about 1 cc. of water and heat gently until all of the crystals have dissolved and the test tube contains only a perfectly clear solution. Place a plug of cotton in the mouth of the tube and allow the latter to stand in the test tube rack undisturbed until perfectly cool. Notice that the tube still contains a perfectly clear solution.

Remove the plug of cotton and drop into the tube a small crystal of sodium acetate. What phenomenon do you observe? Does the temperature of the tube change? Can you offer an explanation of the phenomenon?

41. Efflorescence. On separate watch glasses, expose to the air for several days a few large clear crystals of each of the following substances: ferrous sulphate ($FeSO_4$), sodium sulphate (Na_2SO_4) and zinc sulphate ($ZnSO_4$). What change takes place during the time that they are exposed? Why does this change occur? Mention one or two salts which are not efflorescent.

42. Deliquescence and Hygroscopicity. On separate watch glasses expose to the air, for a day or two, small pieces of each of the following substances: zinc chloride ($ZnCl_2$), calcium chloride ($CaCl_2$), sodium hydroxide ($NaOH$) and phosphorus pentoxide (P_2O_5). What change takes place in the appearance of these substances? What is the difference between the terms "deliquescent" and "hygroscopic"? Which of the above-mentioned substances come in each class?

43. **Water of Decrepitation.** Heat two or three large crystals of sodium chloride ($NaCl$) in a test tube. Explain the phenomenon observed.

In a porcelain mortar grind a few crystals of $NaCl$ to a fine powder. Introduce a portion of this powder into a test tube and heat. Why does the result differ from that obtained when large crystals were employed?

Determination of the Number of Molecules of Water of Crystallization in Gypsum.

(Quantitative.)

44. Carefully weigh a clean dry porcelain crucible without the cover. About half fill the crucible with powdered gypsum and again weigh accurately. The difference in the two weighings gives the weight of gypsum taken.

Place the crucible on a pipestem triangle on a ring stand and apply heat, very gently for a time, and then gradually stronger until the full force of the Bunsen burner is employed. Continue the strong heat for about 5 minutes.

Allow the crucible to cool to the room temperature; then weigh. Again place the crucible on the triangle and heat with the full force of the burner for 5 minutes; allow to cool and weigh. This process of heating should be continued until two successive weighings are identical.

The loss in weight is due to the water of crystallization which has been expelled. Calculate the percentage of water of crystallization which the gypsum contained. What is the percentage of residue, i.e., anhydrous calcium sulphate?

In order to calculate the number of molecules of water of crystallization which the gypsum originally contained, divide the percentage of water of crystallization found by the molecular weight of water. Let this result be represented by *a*. Likewise divide the percentage of residue (anhydrous calcium sulphate) by the molecular weight of calcium sulphate. Call this *b*. The number of times which *a* is greater than *b* equals the number of molecules of water of crystallization which the gypsum originally contained.

Determination of the Specific Gravity of Solids Heavier than Water.

45. Select a suitable piece of the solid to be determined and after thoroughly cleaning, ascertain its exact

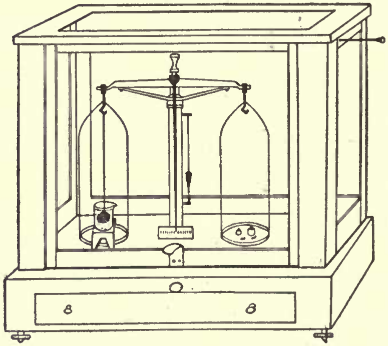


Fig. 10.

weight (W). Then place a small bench over the pan of the balance in such a way that it does not touch the latter. On the bench place a beaker of distilled water large enough to accommodate the sample. By means

of a fine silk thread suspend the sample from the arm of the balance so that the sample hangs in the water and is completely submerged. Ascertain the weight of the sample in water by carefully adding weights to the other pan of the balance. Let the weight in water be represented by W'. (Fig. 10.)

W' is less than W because a substance immersed in water is buoyed up by the water. *The loss of weight in water is equal to the weight of the volume of water displaced*, and from this, *the loss of weight in water is equal to the weight of an equal volume of water.* But *the specific gravity is equal to the weight of the substance divided by the weight of an equal volume of water;* therefore,

$$\text{Specific Gravity} = \frac{W}{W - W'}.$$

HYDROGEN PEROXIDE (H_2O_2).

46. To about 5 gms. of barium peroxide (BaO_2) contained in a beaker add enough water to form a paste. Cool the mixture by adding a little snow or ice. Then add about 25 cc. of cold dilute sulphuric acid. Allow to stand for a few moments so that the barium sulphate will settle. Pour off as much as possible of the supernatant liquid and filter it through a double filter.

This liquid is a solution of hydrogen peroxide (H_2O_2) in water. It is to be used in the following experiments.

47. To a portion of the solution add a little KI-starch paste or merely introduce a piece of filter paper which has been moistened with the test solution. What reaction occurs? What other substance have we studied which gives the same color with this test solution?

48. To another portion of the solution add a solution of potassium permanganate ($KMnO_4$), drop by drop. Is there a gas evolved? What is the gas?

49. Mix a few drops of dilute sulphuric acid and a few drops of potassium dichromate solution in a test tube and to the mixture add about a half inch layer of ether. (CAUTION! *See page 22, Exp. 27.*) Now add several cubic centimeters of hydrogen peroxide solution. This is a good test for hydrogen peroxide and for chromium. What color is produced in the ether?

50. To a little powdered MnO_2 in a test tube add a few cubic centimeters of hydrogen peroxide solution taken from the bottle on the side shelf. (This solution is probably much stronger than the solution made in Exp. 46.) Test the gas evolved. Explain the action.

51. Test the action of H_2O_2 on a solution of titanium sulphate. The color produced is characteristic and the intensity depends upon the strength of the titanium solution.

Summary. State, in general terms, the method for the preparation of hydrogen peroxide. What are two important uses of hydrogen peroxide? Mention some of the common names under which hydrogen peroxide is sold commercially. What is the strength of commercial hydrogen peroxide?

Problems. (a) To prepare 15 liters of 2% H_2O_2 solution, what weight of BaO_2 would be needed? What weight of 25% H_2SO_4 would be required?

(b) If 1 liter of water at 4° C. is converted into the form of steam at 102°, what will be the volume of the steam?

(c) In dehydrating 1 ton of crystallized sodium carbonate by the aid of heat, what weight of water would be driven out?

CHAPTER V.

THE HALOGENS.

CHLORINE (Cl; 35).

52. **Preparation.** In a test tube treat about a gram of manganese dioxide (MnO_2) with a few cubic centimeters of concentrated HCl. Warm gently. Notice the yellowish green gas evolved. Has it any odor?

53. In separate test tubes try the action of concentrated HCl on small portions of each of the following substances: potassium chlorate ($KClO_3$), barium peroxide (BaO_2), potassium dichromate ($K_2Cr_2O_7$), lead dioxide (PbO_2) and calcium hypochlorite ($CaCl_2O$).

54. Make a mixture of about 1 gm. each of MnO_2 and NaCl. Introduce the mixture into a test tube and treat with H_2SO_4 which has previously been diluted with an equal volume of water. (Pour the acid into the water.) Warm the mixture and notice the gas evolved. Can you explain the reaction?

In the above methods of preparation of chlorine, what general principle is involved? Mention another very important commercial method for the preparation of chlorine.

55. Arrange an apparatus as shown in Fig. 11. The flask should be of about 500 cc. capacity. The delivery tube should extend to the bottom of the bottle. Place

25 or 30 gms. of finely granulated MnO_2 in the flask and through the thistle tube add about 100 cc. of concentrated HCl. Agitate the flask to cause the acid and oxide to mix thoroughly.

Warm the flask gently and collect the chlorine evolved in bottles as shown in the drawing, using a cardboard

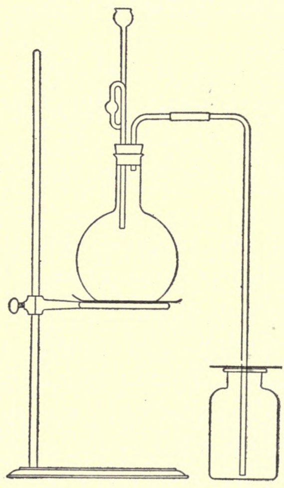


FIG. 11.

or paper cover through which the delivery tube passes. As the bottles are filled they should be covered with glass plates on which vaseline has been smeared. Collect five or six bottles of the gas. (They are to be used in the following experiments on the "properties" of chlorine.)

56. Chlorine Water. Prepare about 200 cc. of chlorine water by passing chlorine gas through that volume of cold water contained in a small flask. To hasten

the absorption of the gas, occasionally shake the flask containing the water. Label this solution and reserve it for later experiments.

57. **Properties of Chlorine.** Into one of the bottles of chlorine drop a little powdered antimony (Sb). Note all phenomena observed. What compound or compounds are formed?

58. In the Bunsen flame heat to redness a thin strip of copper (Cu) foil and quickly plunge into a bottle of chlorine. Notice the products formed. Ascertain if they will dissolve in water and, if so, what color is produced.

59. Introduce into a third bottle of chlorine, by means of a deflagrating spoon, a small piece of yellow phosphorus which has been dried by pressing gently between pieces of filter paper. (CAUTION! *See page 16, Exp. 21.*)

60. Saturate a piece of filter paper with turpentine ($C_{10}H_{16}$), and plunge into a bottle of chlorine. Note the flame and the fumes. Explain what has happened. Bring a piece of wet blue litmus paper to the mouth of the bottle.

61. Moisten a piece of colored calico and suspend it in a bottle of chlorine. Allow to stand for 15 or 20 minutes. Is the color of the cloth changed?

Introduce a colored flower or a few blades of grass into a bottle of chlorine and observe the change which takes place after a few moments.

62. Add a little chlorine water to a few cubic centimeters of indigo solution in a test tube. What change is noticed? What name is applied to such a change?

In like manner, in separate test tubes, add chlorine water to solutions of: cochineal, copper sulphate ($CuSO_4$), litmus and potassium dichromate ($K_2Cr_2O_7$). Why are some of these solutions bleached and others not?

In a beaker of chlorine water immerse a strip of colored calico for a few moments. Does the chlorine water affect the calico in the same manner as the chlorine gas? (Compare with Exp. 61.)

Summary. In what respect is bleaching by chlorine similar to bleaching by hydrogen peroxide? If the red calico and the chlorine gas had both been perfectly dry, would the cloth have been bleached?

Explain in a general way how chlorine bleaches.

Problems. (a) What volume of chlorine at 20° and 740 mm. pressure can be prepared by the action of an excess of HCl on 100 gms. of $K_2Cr_2O_7$?

(b) In order to prepare 1766 liters of chlorine at 18° and 755 mm. pressure, what weight of 83% MnO_2 will be necessary? What weight of 32% HCl will be needed? What volume will this amount of HCl have?

Determination of the Weight of a Liter of Chlorine.

(Quantitative.)

63. Apparatus. Clean, dry flask of about 500 cc. capacity, with tightly fitting cork; thermometer; balance; chlorine generator as shown in Fig. 12, fitted with wash bottle *a* containing H_2O and drying bottle *b* containing concentrated H_2SO_4.

Data Necessary.

Volume of flask,	V
Volume, corrected to 0° and 760 mm.,	V_0
Weight of flask filled with air,	W
Weight of flask filled with chlorine,	W'
Weight of vacuous flask,	F
Observed temperature,	T
Observed pressure,	P
Standard temperature, 0° C.,	T'
Standard pressure, 760 mm.,	P'
Weight of a liter of air at 0° and 760 mm., 1.293 gms.	

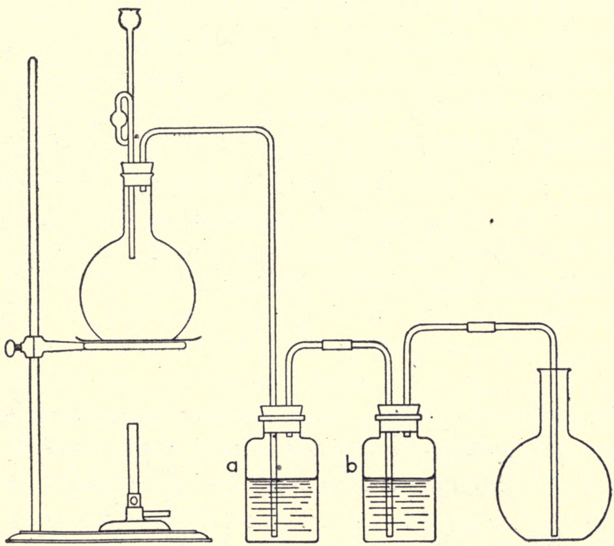


FIG. 12.

Procedure. Carefully weigh the clean, perfectly dry flask and cork (W). Generate chlorine in the apparatus shown in Fig. 12, by means of MnO_2 and concentrated HCl. Let the chlorine gas run into the previously weighed flask until all air is displaced, i.e., until the

flask is entirely filled with the gas. Remove the flask and stopper tightly. Weigh accurately (W'). In order to ascertain the volume of the flask (V), fill it with water to the point where the cork comes when the flask is stoppered. Then carefully measure the water by means of a graduated cylinder. This gives volume of the flask (V). Note the temperature (T) and the pressure (P) in the room at the time the experiment is performed.

Weight of the Vacuous Flask. In order to ascertain the weight of the chlorine, it is necessary to know the weight of the vacuous flask, i.e., the weight when it is not filled with air. This can be readily calculated, for we know the weight of a liter of air at 0° and 760 mm. pressure to be 1.293 gms. and consequently the weight of 1 cc. of air under these conditions is 0.001293 gm. The capacity of the flask is V at T and P. Then the capacity at 0° and 760 mm. pressure will be

$$V_0 = \frac{VT'P}{TP'}.$$

This corrected volume, V_0, multiplied by 0.001293 gm. gives the weight of the air in the flask, and $W - (V_0 \times 0.001293)$ equals the weight of the vacuous flask, or F.

Weight of a Liter of Chlorine. The corrected volume of chlorine is, of course, the same as that obtained for air; or, in other words,

$$V_0 = \frac{VT'P}{TP'}.$$

The actual weight of the chlorine in the flask is equal to $W' - F$. Knowing that V_0 cc. of chlorine weigh

$W' - F$ gms., the weight of a liter of chlorine can be readily calculated from the proportion:

$$V_0 : (W' - F) :: 1000 : x,$$

in which x equals the weight of a liter of chlorine.

What is the vapor density of chlorine? From the vapor density calculate the theoretical weight of a liter of chlorine and compare the result with that obtained experimentally. What is the percentage error?

What is the function of the wash bottle *a* of the chlorine apparatus? What is the function of bottle *b*? Mention two possible sources of error in the determination of the weight of a liter of chlorine if the gas used was not passed through the wash bottle and the drying bottle.

Hydrochloric Acid (HCl).

64. For the generation of hydrogen chloride (HCl), arrange an apparatus as shown in Fig. 11, page 36. Place about 20 gms. of NaCl in the flask and add through the thistle tube 100 cc. of a mixture of equal parts by volume of water and concentrated H_2SO_4. (Pour the acid into the water.) Warm the flask gently and collect the gas evolved by displacement of air, i.e., by the same method used for the collection of chlorine. Collect four or five bottles.

Why not collect the gas over water?

65. Into one of the bottles of gas thrust a burning splinter to ascertain whether the gas (HCl) burns, or supports combustion. What reason can you give for the action?

66. What do you notice when a bottle of the gas is

uncovered? Blow across the open mouth of a bottle of the gas.

Invert a bottle of the gas over water in the pneumatic trough. Then, letting the mouth of the bottle dip below the surface of the water, remove the cover glass. What causes the water to rise?

67. Pour a few cubic centimeters of ammonium hydroxide (NH_4OH) into a clean bottle and shake so that the inside of the bottle will be covered with the liquid. Invert the bottle over one of the bottles containing HCl gas and quickly withdraw the cover glass, thus bringing together the open mouths of the two bottles.

68. Make a solution of HCl gas in water by passing the gas into about 100 cc. of cold water in a small flask. The delivery tube should not extend to the bottom of the flask but should barely touch the surface of the water. Why?

In separate test tubes try the action of this solution on small pieces of magnesium (Mg), zinc (Zn), iron (Fe) and sodium carbonate (Na_2CO_3).

Repeat the tests, using dilute HCl from the reagent shelf instead of the solution made above. How do the results compare?

69. Pour a few cubic centimeters of concentrated H_2SO_4 into a test tube containing about 5 cc. of concentrated HCl. What gas is evolved? Why is it evolved?

70. Into separate test tubes introduce a few cubic centimeters of each of the following solutions: silver nitrate ($AgNO_3$), mercurous nitrate ($HgNO_3$), copper sulphate ($CuSO_4$), lead nitrate ($Pb(NO_3)_2$) and magnesium sulphate ($MgSO_4$). To each tube add a few cubic centimeters of dilute HCl.

Which metals form insoluble chlorides?

Summary. What is the odor of HCl? When we speak of "hydrochloric acid" as a laboratory reagent, just what is meant? What special name can we apply to the gas to distinguish it from the solution? Speaking in general terms, what is the method of preparation of HCl gas?

Problems. (a) Calculate the weight of 7580 liters of HCl gas at 10° and 745 mm. pressure. If this amount of gas is dissolved in the proper amount of water, what volume of 15% HCl will be formed, the specific gravity of 15% HCl being 1.075?

(b) How many liters of 33% HCl (sp. gr. = 1.168) can be prepared by the action of an excess of H_2SO_4 on 180 kilograms of pure sodium chloride?

Oxygen Acids of Chlorine.

71. Hypochlorites. Pass chlorine through 50 cc. of a solution of potassium hydroxide (KOH) contained in a small flask until the liquid is saturated with the gas. What compound is formed?

Introduce a portion of the solution thus obtained into a small beaker and immerse a piece of colored calico in it. Allow to stand for a few minutes.

72. To another portion of the solution prepared above, add a few cubic centimeters of dilute H_2SO_4. What gas is evolved? Repeat, using HCl instead of H_2SO_4.

73. From the bottle on the side shelf obtain a few grams of calcium hypochlorite ($CaCl_2O$), which is commonly called "bleaching lime" or "chloride of lime." Put the powder in a small beaker and add dilute H_2SO_4.

74. In a bottle or tall glass cylinder mix a few grams

of "bleaching lime" with water. Treat the mixture with 10 or 15 cc. of a solution of cobalt chloride ($CoCl_2$) and allow to stand 10 minutes. Notice the gas evolved. Test the gas with a glowing splinter.

75. Chlorates. Pass chlorine into 50 cc. of a hot solution of KOH until the liquid is saturated. (Does chlorine have the same action upon *hot* as upon *cold* KOH?) Evaporate the solution to about half of its original volume and allow to stand and crystallize. If crystals do not separate upon cooling, evaporate the solution to a still smaller volume and again allow to stand and cool, quietly.

What is the composition of the crystals formed? Dry the crystals by pressing them between pieces of filter paper, and reserve them for later experiments.

76. Into a dry test tube introduce a very small crystal of potassium chlorate and treat it with a few drops of concentrated H_2SO_4. (CAUTION.) If the reaction is not noticeable heat the test tube under the hood being careful to protect the face and clothes.

77. Obtain a few cubic centimeters of pure $KClO_3$ solution from the bottle on the side shelf. To this solution add a few drops of a solution of silver nitrate ($AgNO_3$). Also test a few cubic centimeters of potassium chloride (KCl) solution with $AgNO_3$ solution. Is the chlorine in $KClO_3$ in a different state of combination from that in KCl?

78. Into a test tube partially filled with pure $KClO_3$ solution introduce a piece of zinc and enough concentrated H_2SO_4 to cause an evolution of hydrogen. Allow to stand for 5 minutes; then filter and test the clear filtrate with $AgNO_3$ solution. Compare with the previous

experiment. What change has the zinc and H_2SO_4 brought about?

79. Perchlorates. To a small crystal of potassium perchlorate ($KClO_4$) in a test tube add a few drops of concentrated H_2SO_4. Compare with Experiment 76.

In another test tube try the action of concentrated HCl on a few crystals of $KClO_4$. Is chlorine evolved? What is the action of HCl on $KClO_3$?

80. Heat a few crystals of $KClO_4$ in a hard glass test tube and test for evolved oxygen by means of a glowing splinter.

81. Immerse a strip of colored calico in a solution of $KClO_4$. Is the cloth bleached? Repeat with a solution of $KClO_3$.

82. Test the action of a solution of $AgNO_3$ on a solution of $KClO_4$ and compare the results with those obtained in Exp. 77. Repeat Exp. 78, using a solution of $KClO_4$ instead of $KClO_3$.

Summary. What is the relation between "bleaching lime" and sodium hypochlorite? How do these substances bleach? What element have we studied which bleaches in the same way? What is the composition of "eau de Javelle"?

Mention ways in which hypochlorites, chlorates and perchlorates differ in their action with reagents. Why is it that solutions of chlorates and perchlorates do not bleach?

Compare the action of concentrated HCl and concentrated H_2SO_4 on hypochlorites, chlorates and perchlorates and write general equations for each, letting M represent a monovalent metal.

Which oxygen acid of chlorine have we not studied? Why has it been omitted?

BROMINE (Br; 80).

83. Introduce a drop of bromine into a clean, dry 500-cc. flask and warm gently by holding at some distance above the flame. What is the color of the vapor of bromine? Has bromine any odor? (CAUTION! *Great care must be used in handling bromine; it is a dangerous chemical and its vapors are very irritating. Do not get bromine on the hands.*)

84. Introduce a mixture of about 1 gm. each of MnO_2 and potassium bromide (KBr) into a test tube and add a few cubic centimeters of strong H_2SO_4. Warm the mixture gently and notice the gas evolved. How can you describe it? What other element have you prepared by heating one of its compounds with MnO_2 and concentrated H_2SO_4?

85. To a few cubic centimeters of a solution of KBr in a test tube add chlorine water. Does the liquid change in appearance? Why? Which element, Cl or Br, has the stronger affinity for potassium (K)?

86. Into each of three test tubes introduce a few cubic centimeters of bromine water from the bottle on the side shelf. To one add a few cubic centimeters of carbon disulphide (CS_2); to the second, a few cubic centimeters of chloroform ($CHCl_3$); and to the third a few cubic centimeters of ether ($C_4H_{10}O$). Shake each tube gently and then allow to stand for a few minutes. Notice what has taken place. Is bromine more soluble in water or in the reagents used?

87. In a beaker immerse a strip of colored calico in some bromine water. Allow to stand for a few moments.

In separate test tubes try the action of bromine

water on solutions of indigo, cochineal and litmus. Compare the results with those obtained in Exp. 62.

88. Under a hood having a good draught pour a few cubic centimeters of Br into a small beaker or a wide-mouth bottle. Drop a small piece of tin (Sn) foil into the beaker. Explain all phenomena. What compound is formed?

Repeat, using a red-hot piece of thin copper foil instead of tin foil.

89. Into a solution of NaOH pour a few cubic centimeters of Br water and stir. Is the solution brown? What change has taken place? What would have been formed if a hot solution of NaOH had been employed? (Compare with experiments on the oxygen acids of chlorine.)

Put a piece of colored calico into the solution formed by adding Br water to NaOH. Allow to stand for a few minutes. Is the color changed?

Hydrobromic Acid (HBr).

90. To a few crystals of KBr in a small flask add a little concentrated H_2SO_4 and warm. Breathe across the mouth of the flask. How many different products of the reaction can you identify? What are the brown fumes which finally appear in the flask? Why is this not a good method for the preparation of HBr?

91. Arrange an apparatus as shown in Fig. 13, using a 250 cc. flask and a small beaker of water. The stem of the retort should barely dip beneath the surface of the water. Be sure that all connections are tight. Into the flask introduce 5 gms. of red phosphorus (P) and 20 cc. of water. The "U" tube should be filled with

pieces of pumice coated with a mixture of red phosphorus and water.

Through the dropping funnel now introduce 15 cc. of bromine, adding it a drop at a time and agitating the flask after each addition. The HBr generated dissolves in the water in the beaker forming a solution of hydrobromic acid.

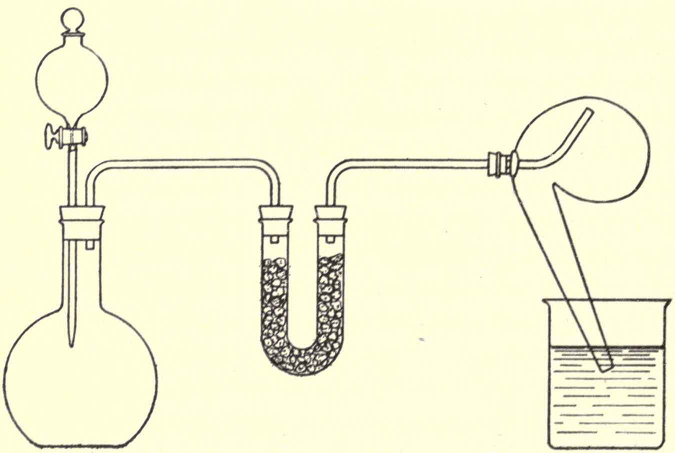


FIG. 13.

Test the solution with litmus paper. Try its action on Na_2CO_3 and on zinc or magnesium. Is it an acid?

92. In separate test tubes try the action of HBr upon solutions of silver nitrate ($AgNO_3$); lead nitrate ($Pb(NO_3)_2$ and mercurous nitrate ($HgNO_3$).

Repeat the experiment, using a solution of KBr instead of HBr. Does it make any difference which is used?

How do the insoluble bromides compare with the insoluble chlorides?

IODINE (I; 127).

93. Introduce a small crystal of iodine into a clean, dry 500-cc. flask and warm gently. Note the color of the iodine vapor. When all the iodine is vaporized, allow the flask to stand and cool. Note the black deposit on the sides of the flask.

Compare the color of iodine and its vapor with bromine and chlorine.

94. Make a mixture of a little MnO_2 and potassium iodide (KI). Place the mixture in a test tube, add a little concentrated H_2SO_4 and warm gently. What is the result?

95. In separate test tubes add a little iodine solution to each of the following: CS_2, $CHCl_3$, alcohol and ether. Shake each tube gently and then allow to stand. What colors are produced? Compare with Exp. 86. Which solvents dissolve iodine to give a solution the color of iodine vapor?

96. To a few cubic centimeters of KI solution add a little chlorine water; then add a few cubic centimeters of CS_2 and shake.

Repeat, using bromine water instead of chlorine.

What do you conclude as to the relative affinity of chlorine, bromine and iodine for potassium?

97. To about 2 cc. of KI solution add strong chlorine water until in decided excess. What great change has taken place? Explain fully.

98. In a test tube treat a small crystal of iodine with alcohol. Note that the iodine dissolves. What is "tincture of iodine"? (Save the solution for use in Exp. 101.)

99. Try the action of iodine water on starch paste. Have you seen this color in any previous experiments? Heat the solution to boiling and then allow to stand and cool. Note all changes.

100. In a test tube treat a crystal of iodine with water and shake. Does the iodine dissolve? To what extent?

Now add a crystal of KI and again shake. Does the addition of KI cause any hastening of solution? Why?

101. To a few cubic centimeters of tincture of iodine add a few drops of water. Why is there a change?

102. To a beaker containing about 50 cc. of water add enough of the solution formed in Exp. 100 to produce a faint yellow color. Add a drop or two of starch paste. What happens? Now add a solution of sodium thiosulphate ($Na_2S_2O_3$), a drop at a time, until in excess. Explain all changes.

Hydriodic Acid (HI).

103. To a few crystals of KI in a small flask add concentrated H_2SO_4 and warm gently. Breathe over the mouth of the flask; are there any white fumes? Continue to heat gently and notice all the products formed by the reaction. Explain by equations.

104. To about 50 cc. of water in a small beaker or flask add a little powdered iodine. Pass hydrogen sulphide (H_2S) gas through the solution until all iodine disappears. What is the white substance formed? What is in solution?

Filter the solution and test the clear filtrate with blue litmus paper. In separate test tubes try the action of the solution on zinc and on Na_2CO_3.

105. In separate test tubes add KI solution to solutions of $AgNO_3$, $HgNO_3$, $Hg(NO_3)_2$, $NiSO_4$ and $Pb(NO_3)_2$. Which metals form insoluble iodides?

FLUORINE (F; 19).

Hydrofluoric Acid (HF).

106. Coat the concave side of a watch glass with paraffin by warming gently and rubbing with a small piece of paraffin. When cold, scratch a design in the paraffin. Carefully pour a few cubic centimeters of hydrofluoric acid (HF) on the glass and hold it so that the acid will come into contact with the glass where the paraffin has been scratched away.

Remove the excess of paraffin, after washing away the acid, by warming the glass or by wiping it off with a cloth wet with alcohol. Examine the clean glass. (CAUTION! *HF is a very dangerous chemical. Do not get it on the hands — it makes very bad sores. Do not breathe the vapors — they are very poisonous.*)

107. Coat one side of a piece of window glass with paraffin and scratch a design through the latter.

Place about 2 gms. of calcium fluoride (CaF_2), commonly called "fluorite" or "fluorspar," in a lead dish and moisten with enough concentrated H_2SO_4 to form a thick paste. Place the glass, paraffin side down, over the dish and allow to stand overnight.

Then clean the glass and notice the design etched upon the surface.

108. Into a test tube introduce a mixture of about 1 gm. each of sand or powdered quartz (SiO_2) and CaF_2. Add a little strong H_2SO_4. Warm and at the same time hold a glass rod with a drop of water at the end, in the

mouth of the test tube. What causes the water to become turbid? For what is this a good qualitative test?

109. In separate test tubes try the action of sodium fluoride (NaF) solution on solutions of $AgNO_3$ and $Ca(OH)_2$.

For the sake of comparison, try the action of NaCl on solutions of $AgNO_3$ and $Ca(OH)_2$.

Summary. To what family of elements does fluorine belong? What other elements are included in this family? Write a general equation for the preparation of the halogens, letting X represent halogen. Can fluorine be prepared by heating one of its salts with MnO_2 and H_2SO_4? Why? How is it possible to prepare the element fluorine?

In what respects does fluorine differ from the other halogens? Why is hydrofluoric acid always kept in wax or lead bottles?

Problems. (a) The specific gravity of sea water is 1.025, and it contains 0.36 part of $MgBr_2$ per 1000. How many cubic centimeters of bromine can be obtained from 1 cubic meter of sea water. Specific gravity of Br = 3.18.

(b) To make 12 liters of a 35% solution of sodium hypobromite (specific gravity = 1.24), how many grams of NaOH and how many cubic centimeters of bromine are necessary?

(c) How many grams of iodine can be obtained as a by-product from 10 tons of "caliche" (Chili saltpeter) containing 1.3% of sodium iodate?

(d) 18 gms. of iodine will occupy what volume if vaporized at 40° and 765 mm. pressure?

(e) How many grams of 17% HF solution can be prepared from 325 gms. of fluorspar?

CHAPTER VI.

ACIDS, BASES AND SALTS.

110. To a beaker of water add a few drops of concentrated HCl. Taste the solution thus formed. Try the action of the solution on litmus paper, on turmeric paper and on a solution of phenolphthalein.

111. Repeat the preceding experiment, using a few drops of NaOH, a base, instead of HCl. Test as before.

112. In a porcelain evaporating dish add dilute HCl to 20 cc. of dilute NaOH until the solution is neutral to litmus paper. Take out the litmus paper and then evaporate the solution to dryness. Taste the residue. What sort of a compound is it?

113. By means of a deflagration spoon burn a small piece of metallic sodium (Na) in a 500-cc. flask. Add a little water, shake the flask and then test the reaction of the water towards litmus. Does the water contain an acid or a base?

Repeat the experiment, burning a small piece of phosphorus (a non-metal) instead of the sodium. Is a base or an acid formed in this experiment? (The flask should be thoroughly cleaned before this second part of the experiment is performed.)

The oxide of a metal + water forms what kind of a compound? The oxide of a non-metal + water forms what kind of a compound?

114. Boil a little NaOH solution and test the vapors with wet turmeric paper. Is there any change in color? Repeat, using NH_4OH instead of NaOH.

How does ammonium hydroxide differ from other bases in its physical properties?

Acid, Basic and Neutral Salts.

Basicity of an Acid.

115. Pour a little $SbCl_3$ solution into a small beaker of water. What happens? What kind of a compound is the white precipitate? What happens when concentrated HCl is added to the white precipitate?

116. In a porcelain evaporating dish carefully neutralize 20 cc. of dilute H_2SO_4 with NaOH. Evaporate to dryness and heat gently. Dissolve the residue in a little water and test the action of the solution towards litmus.

Now add another 20 cc. of dilute H_2SO_4 to the solution and again evaporate to dryness. Dissolve the residue in water and test its reaction towards litmus.

Do the two parts of this experiment yield different results? How can you account for it? What kind of a salt is the one obtained last? What is the basicity of H_2SO_4?

Repeat, using HNO_3 in each case instead of H_2SO_4. Are two different products formed? What is the basicity of HNO_3?

117. Test the reaction towards litmus paper of solutions of the following compounds: $CuSO_4$, Na_2HPO_4 $NaHCO_3$, Na_2CO_3, $ZnSO_4$, NaCl and $MgSO_4$.

Do all neutral salts have a neutral reaction? Which of the above are exceptions?

Do all acid salts have an acid reaction? Which are exceptions?

Name a neutral salt that has an acid reaction, one that has a neutral reaction and one that has a basic reaction.

Summary. Do all acids contain oxygen? What one element is always present in an acid? What name is applied to those acids which contain oxygen?

What is characteristic about the formula for an acid? For a base? Is water an acid or a base? Why? What is characteristic about the formula for an acid salt? For a basic salt?

Which of the following are acids, which are bases and which are salts: H_3PO_4, NaI, HI, H_2MoO_4, $Al(OH)_3$, H_2SO_4, $Fe(OH)_3$, $FeSO_4$, H_3BO_3, NH_4OH?

Which of the following do you consider as acid salts, which are neutral salts and which are basic salts: Na_3PO_4, $NaHCO_3$, $Pb(OH)(NO_3)$, $CaH_2(CO_3)_2$, Na_2HPO_4, NaCl, $CaCO_3$, $NaHSO_4$, $NaKSO_4$, $Mn_2(OH)_2CO_3$?

What is meant by the basicity of an acid? Give examples of mono-, di-, and tribasic acids. What is meant by the acidity of a base?

Acidimetry and Alkalimetry.

(Quantitative.)

118. Obtain from the instructor a supply of standard H_2SO_4 solution of known strength. What weight of absolute H_2SO_4 does each cubic centimeter of this solution contain? To what weight of NaOH is each cubic centimeter equivalent?

Rinse out a burette twice with small portions of the acid solution and then completely fill the burette with the same solution. In a clean flask obtain from the instructor an unknown sample of NaOH solution to test by means of the acid solution in the burette. This method of testing is known as "titration" and is performed as follows: Add to the contents of the flask

two or three drops of phenolphthalein solution to serve as an "indicator." The alkali turns the phenolphthalein bright red.

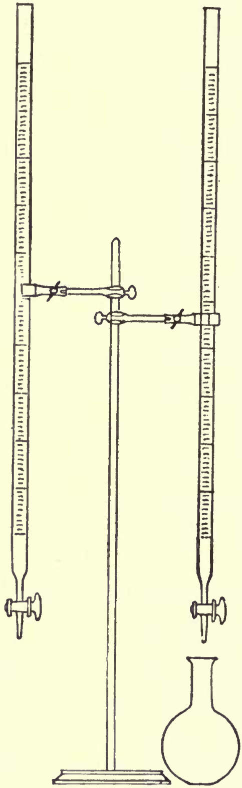


FIG. 14.

Read the level of the acid in the burette and then carefully allow the acid to run drop by drop into the flask containing the alkali and indicator, until the alkali is neutralized. When the alkali is completely neutralized, the addition of one more drop of acid will completely discharge the red color; therefore continue to add acid until one drop finally causes the red color to disappear. Again read the level of the acid in the burette and calculate the weight of NaOH which was in the solution in the flask. (Fig. 14.)

Obtain two other samples of unknown alkali from the instructor and titrate in the same manner.

Standardization of an Alkali Solution. Obtain from the instructor a supply of the alkali solution to be standardized. Fill the other burette with this solution after having first rinsed it out twice with small portions. Into a clean flask carefully measure out from the burette 10 cc. of the alkali solution. Add two or three drops of the indicator and then titrate with the known acid solution in the other burette as

described previously. Make three titrations, take the average reading and calculate the strength of the alkali solution and its H_2SO_4 equivalent per cubic centimeter.

Now obtain from the instructor samples of unknown acid to determine by means of this "standardized" alkali solution. The method of titration is practically the same, though the solution after the addition of the indicator is colorless and is titrated with the alkali until a drop of the latter finally produces a faint permanent pink color. The point at which the indicator shows a change in color is called the "end point."

For further exercises in "acidimetry and alkalimetry" obtain instructions from the instructor.

CHAPTER VII.

NITROGEN (N; 14).

119. Preparation. Place a small piece of phosphorus on a porcelain crucible cover or on a piece of

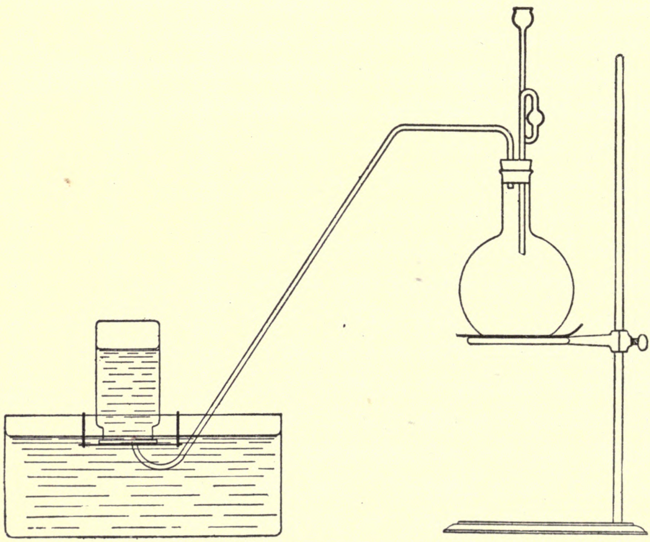


FIG. 15.

cork floating on water. Ignite the phosphorus by touching it with a hot file, and quickly cover with an inverted beaker or bottle, allowing the latter to dip into the water.

Note the white fumes. When combustion is complete, note the decrease in volume of the gas in the bottle. What does this decrease represent? Allow the bottle to stand in the water for a time. Do the white fumes disappear? Why?

Test the gas remaining in the bottle as directed in Exp. 121.

120. Arrange an apparatus as shown in Fig. 15. Into the flask put 25 cc. of water, 10 gms. sodium nitrite ($NaNO_2$) and 5 gms. ammonium chloride (NH_4Cl). Heat the mixture gently and collect two or three bottles of the gas. Test the gas as directed in the following experiment.

121. Properties. Test the samples of nitrogen prepared in the two preceding experiments by introducing a burning splinter into the bottles. Does nitrogen burn? Does it support combustion? Do the two samples of nitrogen give the same test?

Has the gas any odor? Is nitrogen soluble in water? Has it any reaction towards litmus paper?

Determine whether nitrogen will support the combustion of sulphur.

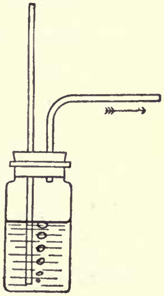


FIG. 16.

Air.

122. Tests for Impurities. Arrange a bottle as shown in Fig. 16. Introduce lime water or baryta water into the bottle and draw air through the solution by attaching the bottle to the suction pump. Allow this experiment to run for some time. Test the precipitate formed by adding HCl. If this produces an effervescence, the pre-

cipitate was a carbonate, hence the solution took carbon dioxide from the air. What do you know of the relative amounts of this impurity in the air in the country and in the city?

By what means can you detect moisture in the air? What are some of the other impurities always present in the air? Mention several other impurities which may be present in the air in the laboratory. How can you detect these?

Analysis of Air.

(Quantitative.)

123. Procuring the Sample. Disconnect the apparatus (Fig. 17) at point *f*. Open the stopcock in tube *a* of the gas burette and raise tube *b* until *a* is completely filled with water. Now lower *b*, thus allowing air to enter *a*. Hold the two tubes in such a way that the water is at the same level in both and *a* contains just 50 cc. of air. While still holding the tubes in this position, close the stopcock in *a*.

Connecting the Apparatus. Gently blow into the rubber tube *d* attached to the gas pipette, thus forcing the alkaline pyrogallic acid solution contained in *c* up through the capillary tube *e*. When *e* is completely filled with the liquid, pinch the rubber tube *d* to prevent the liquid from flowing back, and, while doing this, connect *e* to *a* at point *f* by means of a short piece of rubber tubing, as shown in Fig. 17. The pressure on rubber tube *d* may then be released.

If everything has been done correctly up to this point, tube *a* will contain 50 cc. of air, and bulb *c* and tube *e*

will be completely filled with the alkaline pyrogallic acid solution.

Absorption of the Oxygen. Open the stopcock in *a* and elevate *b* in order to force all of the air in *a* through

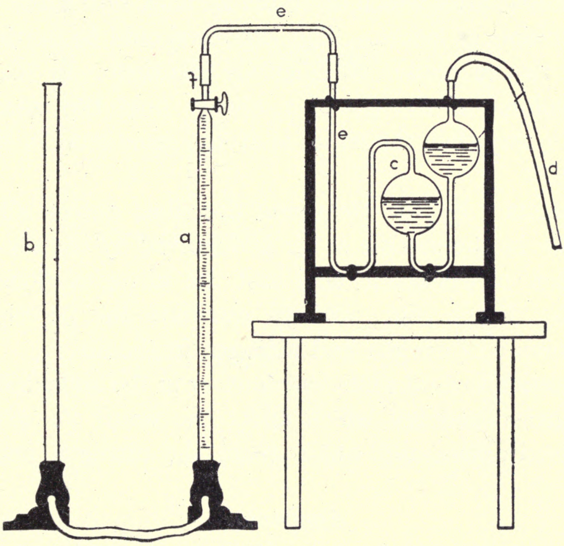


FIG. 17.

tube *e* into the gas pipette. As soon as all of the air is in *c*, close the stopcock in *a*. (Tube *a* and tube *e* will then be completely filled with water.)

Without disconnecting the apparatus, gently agitate the pipette in order to bring the air into better contact with the alkaline pyrogallic acid solution. Continue to shake for about 10 minutes. Then open the stopcock in *a* and lower *b*, thus causing the air to be driven back into the tube *a*. As soon as all air has reëntered *a*, and tube *e* is completely filled with the solution from *c*, close

the stopcock in *a*. Hold *a* and *b* in such a manner that the water in them will be at the same level; then read the volume of air in *a*.

Force the air into *c* a second time and shake for about 5 minutes, after which drive the air back into *a* and read the volume as before. This process should be continued until two successive readings are identical. In reading the volume of the gas in *a*, always hold the tubes in such a way that the water is at the same level in both. (Why?)

Results. By the treatment described above, all the oxygen in the sample of air is dissolved by the alkaline solution of pyrogallic acid and the nitrogen alone remains. From your readings calculate the percentage by volume of oxygen and nitrogen in the air.

Mention several gases which occur in the air in minute quantities, and tell which affect the result for oxygen obtained above and which affect the nitrogen percentage.

Ammonia.

124. Test. Hold a piece of moist red litmus paper near an open bottle of ammonium hydroxide and notice the change in color. Repeat, using moist turmeric paper instead of litmus.

Notice the odor of ammonium hydroxide. Why has this liquid an odor? Why are the litmus and turmeric paper changed when brought near the open bottle?

125. Preparation. For the preparation of ammonia use the apparatus shown in Fig. 18. The drying tube should be filled with small dry pieces of soda-lime. Into the flask introduce a mixture of about 30 gms. each of NH_4Cl and slaked lime, $Ca(OH)_2$. Heat gently and

collect the gas by displacement of air. Collect several bottles, cover with glass plates, and save for use in Exp. 130.

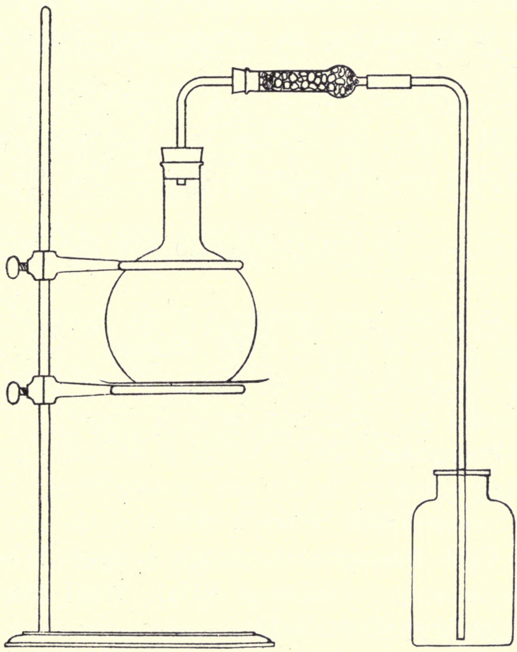


FIG. 18.

126. In a test tube gently warm a mixture of NaOH or KOH and a solution of some ammonium salt. Hold a piece of moistened litmus paper near the mouth of the test tube. Repeat with another ammonium solution.

127. In separate test tubes heat bits of leather, glue or egg albumen with small amounts of soda-lime. Is there a gas evolved? Note the odor and test with moist turmeric paper.

128. In a hard glass test tube strongly heat about 20 gms. of iron turnings or filings with 2 gms. of KNO_3. Test the escaping gas with a burning splinter.

In like manner heat 20 gms. of iron filings with 2 gms. of solid KOH and test the escaping gas with a lighted splinter.

Make a mixture of 2 gms. each of iron turnings, KNO_3 and KOH. Heat the mixture in a test tube and test the escaping gas with turmeric paper. Has the gas an odor?

Explain fully the results obtained from the three parts of this experiment.

129. In a test tube dissolve a small crystal of KNO_3 in about 5 cc. of strong KOH solution. Add a little metallic aluminum (wire or turnings) and heat. Test the escaping gas with wet turmeric paper.

130. Properties. Test a bottle of ammonia gas with a burning splinter. Is the gas combustible? Does it support combustion? Open a bottle of the gas under water. Does the water rise in the bottle? What can you say as to the solubility of NH_3? What other very soluble gas have we studied?

Hydroxylamine.

131. In separate test tubes try the action of hydroxylamine hydrochloride solution on solutions of mercuric chloride ($HgCl_2$) and copper sulphate ($CuSO_4$). What kind of an action has the reagent on these solutions?

What is the formula for hydroxylamine hydrosulphate? What other compounds of nitrogen and hydrogen have you studied? Tell the properties of each.

Determination of the Weight of a Liter of Ammonia.

(Quantitative.)

132. Proceed exactly as described in the experiment on the determination of the weight of a liter of chlorine (Exp. 63, page 38). The ammonia can be generated by means of the apparatus as described in Exp. 125, or it may be generated by simply boiling a strong solution of ammonium hydroxide. In both cases, the gas should be dried by passing through a tube containing soda-lime.

Why not dry the gas with concentrated sulphuric acid as in the case with chlorine? Why is it not necessary to wash the ammonia as was done with chlorine? What would happen if this were done?

Nitrous Oxide (N_2O).

133. Arrange an apparatus as shown in Fig. 19, using a flask of about 250 cc. capacity. Introduce about 25 gms. of dry ammonium nitrate (NH_4NO_3) into the flask and heat gently. After the gas begins to be evolved steadily and all air has been driven from the apparatus, collect several bottles of the gas by displacement of water.

134. Introduce a glowing splinter into a bottle of the gas. What other gas have you studied which affects a glowing splinter in the same way? Mention several tests by which these two gases can be distinguished.

135. By means of a deflagrating spoon introduce into a bottle of the gas a little sulphur which is burning only feebly. Repeat the test, first heating the sulphur highly

so that it burns strongly. Is the result the same? Why?

136. Burn a piece of phosphorus in the gas. What products are formed?

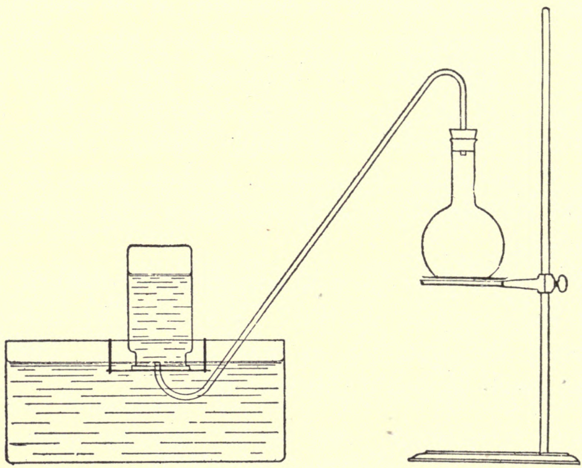


FIG. 19.

Invert a bottle of the gas in water and allow to stand until the end of the laboratory period. Does the water rise in the bottle? What can you say of the solubility of nitrous oxide?

Nitric Oxide (NO).

137. Introduce about 15 gms. of copper turnings into an apparatus as shown in Fig. 2, page 5. Add enough warm water to cover the copper, and then add, through the thistle tube, enough concentrated HNO_3 to cause a brisk evolution of gas. When all air has been driven

from the flask, collect several bottles of the gas over water. Note the color of the gas in the bottles.

138. Open a bottle of the gas so that it comes into contact with the air. What pronounced change immediately takes place?

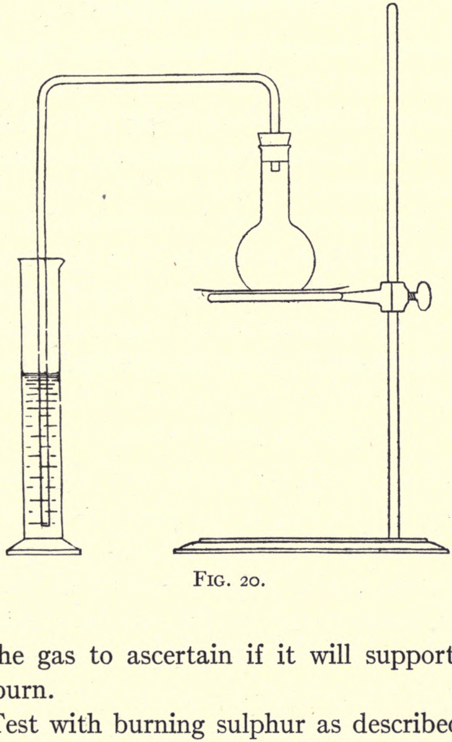


FIG. 20.

Test the gas to ascertain if it will support combustion or burn.

139. Test with burning sulphur as described in Exp. 135. Does it make a difference whether the sulphur is burning feebly or strongly?

Likewise test with phosphorus, first, burning feebly, and second, burning strongly. Explain all phenomena observed.

140. Pass NO into a solution of ferrous sulphate ($FeSO_4$) in a test tube. When the solution has changed color, remove the test tube and heat the solution to boiling. Is there another change?

Nitrogen Trioxide (N_2O_3).

141. In a test tube gently heat a mixture of a few grams of arsenious oxide (As_2O_3) and a few cubic centimeters of concentrated HNO_3. Notice the color of the fumes produced. If the fumes were condensed to a liquid, what would be the color?

142. In like manner heat concentrated HNO_3 with starch in a small flask arranged with delivery tube as shown in Fig. 20. Pass the gas through about 15 cc. of water. Test the reaction of this aqueous solution towards litmus paper. Save the solution for use in Exp. 144.

Nitrous Acid (HNO_2).

143. Prepare HNO_2 by passing NO through 10 cc. of concentrated HNO_3 which has been previously diluted with 5 cc. of water. Does the solution change in color?

144. Try the action of the nitrous acid thus formed on $KMnO_4$ solution and on KI solution. Add a little to a beaker of water containing a few drops of KI-starch paste.

Repeat these tests, using the solution prepared in Exp. 142 by passing N_2O_3 into water.

145. Sodium Nitrite. In an iron dish heat a mixture of 10 gms. of $NaNO_3$ and 25 gms. of metallic lead. Allow the resulting dark brown mass to cool, extract with water and filter.

Test a portion of the solution for a nitrite by adding a little dilute H_2SO_4 and a few drops of KI-starch paste.

To another portion add a little solid NH_4Cl and warm. Test the gas evolved. What is it?

Nitrogen Tetroxide (N_2O_4).

146. Heat a few grams of powdered lead nitrate ($Pb(NO_3)_2$) in a dry test tube and notice the colored fumes produced. Have you noticed fumes of this color before? Mention another manner in which this gas, N_2O_4, is formed. What other gas has the same color as N_2O_4?

Note the odor of N_2O_4, but breathe very little of the gas inasmuch as it is poisonous.

147. Using an apparatus as shown in Fig. 20, generate N_2O_4 by heating $Pb(NO_3)_2$ and pass the gas into 15 cc. of water. Does the water change in color? Does the gas appear to be very soluble in water?

Test the aqueous solution thus formed by means of litmus paper. Is it an acid or a base? What compounds are contained in the water? What could be added to prove the presence of one of these?

Nitric Acid (HNO_3).

148. Introduce 25 gms. of $NaNO_3$ and 15 cc. of concentrated H_2SO_4 into a glass stoppered retort arranged as shown in Fig. 21, with a test tube for a receiver. The test tube is cooled in a dish of cold water, preferably containing a little ice. Heat the retort and collect the nitric acid which distills. When sufficient acid has distilled, completely remove the retort and test tube from the water.

149. What is the color of the HNO_3 prepared in Exp. 148? To what is the color due? Using a long glass tube, bent at a right angle, blow through the acid in the test tube for several minutes. Does the color change?

Drop a small piece of copper into the test tube of acid. If the liquid in the tube is HNO_3, what will be produced when it comes into contact with the copper?

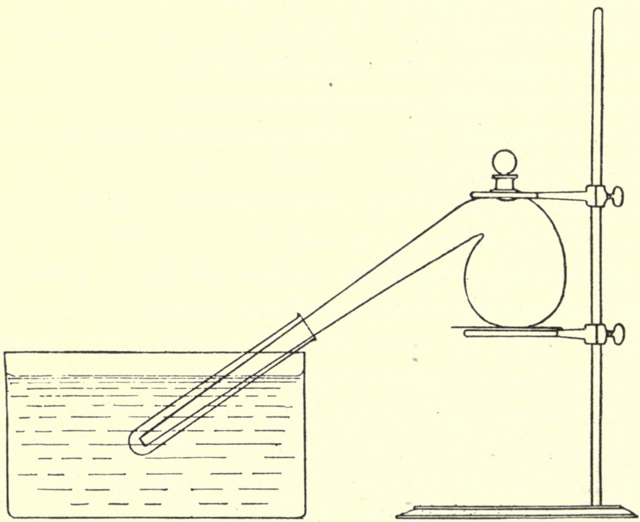


FIG. 21.

150. In separate test tubes try the action of HNO_3 on zinc, iron, lead and tin. Perform these tests under the hood. Write all equations.

151. Treat a little sulphur with concentrated HNO_3 in a test tube and boil for a few moments. Does the sulphur dissolve? What has become of it? Add a few drops of $BaCl_2$ solution to the contents of the test tube — a white precipitate proves the presence of sulphuric acid.

152. In like manner boil concentrated HNO_3 with a little phosphorus. Test a portion of the solution formed with ammonium molybdate solution. This reagent gives a yellow precipitate with phosphoric acid, best upon gently warming.

Explain fully the manner in which HNO_3 oxidizes.

153. Place a drop of concentrated HNO_3 in the palm of the hand. After a few seconds wash off the acid and treat the spot with NH_4OH, which neutralizes the acid. Wash and dry the hand and examine to see if the acid has left any stain. What is formed by the action of nitric acid on flesh?

What is guncotton? Nitroglycerine?

154. **Test for Nitric Acid and Nitrates.** In a test tube make a mixture of about equal parts of $FeSO_4$ solution and a solution of the substance to be tested for nitrates. Now carefully add a few cubic centimeters of concentrated H_2SO_4, holding the tube in an inclined position so that the acid will run down the side to the bottom without mixing with the solution. Allow the tube to stand quietly for several minutes. If a nitrate is present, a brown or black ring will develop at the point where the acid and the solution are in contact.

Explain this test fully and write all equations. Obtain several salts from the instructor and test them to find which are nitrates.

Aqua Regia.

155. Mix about 1 cc. concentrated HNO_3 with 3 cc. concentrated HCl in a test tube and warm the mixture gently. Is a gas evolved? If so, has it any odor? What is the gas? Explain the reaction. Would a

mixture of H_2SO_4 and HCl react in the same way? Why?

156. Introduce small pieces of gold foil into each of two clean dry test tubes. To one add a few drops of concentrated HNO_3 and to the other a little concentrated HCl. Do you notice any reaction?

Heat the contents of each tube to the boiling point. Does this cause the gold to dissolve? While still hot, pour the contents of one tube into the other and note the result. Mention another metal which dissolves in aqua regia but is not soluble in either HCl or HNO_3. (Label the solution of gold in aqua regia and save for a future experiment.)

Nitrogen Iodide (NI_3).

157. In a small beaker treat 10 cc. of tincture of iodine with 15 cc. of strong NH_4OH. Filter and wash the brown precipitate on the filter. Tear the paper into four pieces and spread them on the desk to dry. When perfectly dry, touch them one at a time with a glass rod. (CAUTION!)

Summary. How many oxides of nitrogen are there? Which is the most stable oxide? Why? How many acids of nitrogen are possible? How many of them are common? In what two ways does nitric acid act?

Problems. (a) What weight of copper will be necessary to produce, when treated with an excess of HNO_3, 1200 liters of NO at 10° and 760 mm. pressure?

(b) How many pounds of 65% HNO_3 can be obtained from 1 ton of caliche containing 85% $NaNO_3$?

(c) What weight of phosphorus would be necessary to burn all the oxygen in 1 cubic meter of air? What volume of nitrogen at 22° and 735 mm. pressure would be left?

CHAPTER VIII.

OXIDATION AND REDUCTION.

158. Burn a piece of wood. What is the chief ingredient in the wood? What becomes of it in burning? Is this a case of oxidation or of reduction? How does the burning of wood compare with the rusting of iron?

159. Heat the solution of gold chloride ($AuCl_3$) obtained in Exp. 156 to boiling for a moment. Cool the solution under the faucet. Then add a few cubic centimeters of stannous chloride ($SnCl_2$) solution. Allow to stand for a few moments and notice the change. What sort of a change is this? How does this experiment compare with Exp. 14? Why was the solution boiled before adding the $SnCl_2$?

Does oxidation always mean the adding of oxygen? Does reduction always mean taking away oxygen?

160. To a few cubic centimeters of a fresh solution of ferrous sulphate ($FeSO_4$) add a few drops of KCNS solution. Does this produce any change in the appearance of the iron solution?

To a second portion of the $FeSO_4$ solution add a few drops of concentrated H_2SO_4 and a drop of concentrated HNO_3. Heat to boiling. Cool by holding under the faucet. When cool, test with a few drops of KCNS solution. Is there a change this time? Explain why these two tests differ. In the second test, has the iron been oxidized or reduced? What was the agent which brought about this oxidation or reduction?

161. To a few cubic centimeters of ferric chloride ($FeCl_3$) solution add a drop of KCNS. Compare with the previous experiment.

To a second portion of $FeCl_3$ solution add a few cubic centimeters of $SnCl_2$ solution and then test with KCNS. What difference do you observe in these two tests? Explain fully.

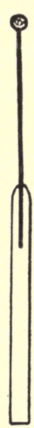


FIG. 22.

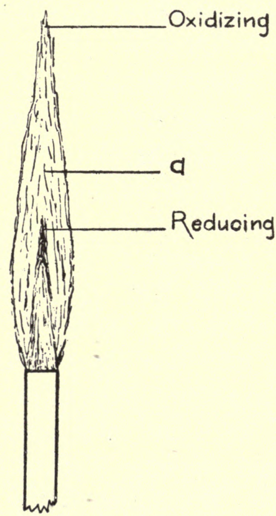
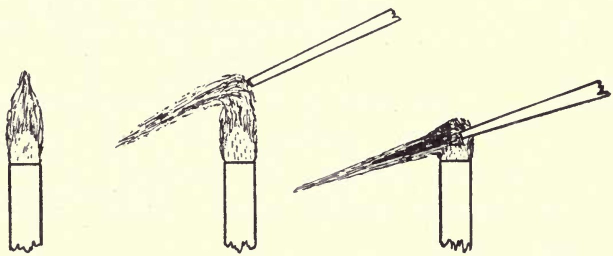


FIG. 23.

162. Oxidizing and Reducing Flame. Make a borax bead in a loop at the end of a piece of platinum wire as shown in Fig. 22. To make the bead, heat the wire to redness and plunge into some borax. Again heat until the borax which clings to the wire has melted and no longer effervesces. If the loop is not completely filled with borax, add more in the same way. Heat the bead until it is perfectly clear.

Pick up a minute particle of MnO_2 with the hot bead and then heat in the hottest part of the flame (shown at *a* in Fig. 23) until the bead is completely fused. Then raise the bead in the flame until it is in the oxidizing flame as shown in the drawing. After a few moments, withdraw the bead from the flame, allow to cool and then examine carefully. Is the bead colored?



a b c

FIG. 24.

Again melt the bead in the hot part of the flame and hold for several minutes in the reducing flame as shown in Fig. 23. Then lower it into the green cone to cool. Quickly withdraw from the flame and examine. Has the color changed? What is the explanation?

Heat the bead in the oxidizing flame again. Does it change to the original color?

In a similar manner try the action of the oxidizing and the reducing flames on borax beads containing traces of copper, cobalt, iron and chromium compounds respectively. Tabulate results.

163. **The Blowpipe.** For use with the blowpipe, a small luminous flame is preferable, as shown at *a* in Fig. 24. To produce the reducing flame, shown at *b*, hold

the tip of the blowpipe just outside the upper part of the flame and blow gently and evenly into it.

The oxidizing flame is produced by blowing a strong blast into the flame as shown at *c*, holding the tip of the blowpipe in the lower part of the flame.

Make a borax bead with MnO_2 and try the action of the oxidizing and the reducing blowpipe flames upon it.

164. Try the blowpipe flames on borax beads containing respectively particles of iron and copper compounds.

Summary. Make a list of all the oxidizing agents you have studied. Make a similar list of all the reducing agents you have studied. Can you name any other oxidizing agents or reducing agents? Define oxidation and reduction.

What acid have you studied which is neither an oxidizing nor a reducing agent?

In what does "combustion" differ from "oxidation"? Can oxidation take place in solution? Can combustion?

CHAPTER IX.

SULPHUR (S; 32).

165. Place about 5 gms. of roll sulphur in a test tube and heat very gently and gradually. Notice the thin, straw-colored liquid which is formed when the sulphur first melts. Now increase the heat gradually and note all changes in appearance.

166. To a solution of calcium polysulphide (CaS_5) add HCl. To a solution of sodium thiosulphate ($Na_2S_2O_3$) add dilute H_2SO_4. What precipitates are formed in these two experiments? Does it make any difference what acid is used?

167. Put about 5 gms. of sulphur in a test tube and apply heat gently just to melt the sulphur. Pour the thin, straw-colored molten sulphur into a beaker of water. Examine the product.

In a second test tube melt about 5 gms. of sulphur and heat to the boiling point; then pour into a beaker of water. Examine the product formed. Does it differ from that formed in the first part of the experiment? Reserve the product for several days and examine for changes.

168. Melt some sulphur in a small Hessian crucible, keeping the temperature as low as possible. Continue to add sulphur until the crucible is full of the liquid.

Allow to cool until the sulphur begins to solidify on the sides of the crucible; then pour out the molten sulphur. Carefully examine the crystals which line the crucible.

169. Place about 10 gms. of flowers of sulphur in a small flask and add 15 or 20 cc. of carbon disulphide (CS_2). (CAUTION! *Never work with CS_2 when a flame is near.*) Shake for a minute or two and then filter, allowing the filtrate to run into a small beaker. Allow the beaker containing the CS_2 to stand quietly. When the CS_2 is all evaporated, what is left in the beaker? Compare this product with that obtained from Exp. 168 in which sulphur was melted in a Hessian crucible.

170. Sulphur Monochloride (S_2Cl_2). Arrange an apparatus as shown in Fig. 25. The distilling flask should contain about 30 gms. of sulphur. Generate chlorine by means of MnO_2, NaCl and H_2SO_4 and pass the gas into the distilling flask as shown. The second distilling flask, which acts as a condenser and receiver, is cooled by means of a stream of water.

When the stream of chlorine becomes regular, heat the distilling flask to melt the sulphur and to distill the S_2Cl_2 formed. The thermometer shows the temperature of the vapor of the latter. Do not let the temperature rise above 160° or 170°.

When sufficient S_2Cl_2 has been obtained, stop the operation and thoroughly clean and dry the distilling flask. Then introduce the S_2Cl_2 and stopper the flask with a cork carrying only a thermometer. Connect the apparatus as shown and redistill the liquid, being careful to note the temperature at which it distills.

171. Describe fully the properties of sulphur monochloride. What sort of an odor has it? Drop a little of the liquid into water and note the effect. To a few drops of linseed oil in a test tube add a few drops of S_2Cl_2. What happens?

Summary. How many varieties of sulphur are there? What name do we apply to various forms of the same element? What other element have we already studied which has more than one form? What is the difference between "roll sulphur" and "flowers of sulphur"?

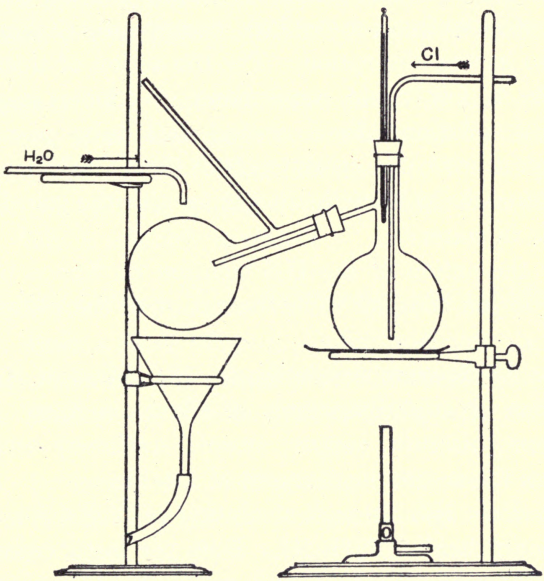


FIG. 25.

Hydrogen Sulphide (H_2S).

172. Add a few drops of HCl to a small piece of iron sulphide (FeS) in an evaporating dish or test tube. Does the gas which is formed have an odor?

173. Arrange an apparatus for generating H_2S similar to that used for hydrogen (Fig. 3, page 7). In the flask place a few lumps of FeS and through the funnel

gradually add dilute HCl until a regular evolution of the gas results.

Collect a bottle of the gas by displacement of air and apply a match. Does the gas burn or support combustion? What are the products formed?

174. Pass a stream of H_2S for several minutes through 50 cc. of water in a 100-cc. flask, occasionally shaking the flask to hasten absorption. Try the action of this solution on a few cubic centimeters of copper sulphate ($CuSO_4$) solution. In a second test tube pass H_2S through a few cubic centimeters of $CuSO_4$ solution. Is the action the same with the gas as with the solution of the gas in water?

Try the action of the H_2S solution on litmus paper. What do you consider to be the nature of the compound H_2S?

175. In separate test tubes try the action of H_2S on solutions of any compounds of silver, mercury, lead, cadmium, bismuth, copper, arsenic, antimony and tin. Express the results in the form of a table.

176. Pass H_2S through a solution of $NiSO_4$ for a few moments; then add NH_4OH. Does the latter cause any change to take place? Why?

Make a solution of ammonium sulphide ($(NH_4)_2S$) by passing H_2S gas through 50 cc. of dilute NH_4OH. Try the action of this solution on solutions of any compounds of iron, cobalt, nickel, manganese and zinc. Express all results in the form of a table as in the previous experiment.

177. Pass H_2S through a few cubic centimeters of concentrated HNO_3 in a small flask. What happens? Can you write the equation?

Pass H_2S through a few cubic centimeters of concentrated H_2SO_4 in a small flask. Write all equations.

What sort of an action has H_2S in these two cases?

178. Try the action of H_2S gas on a few cubic centimeters of potassium dichromate ($K_2Cr_2O_7$) solution containing a few drops of concentrated HCl. Repeat, using potassium permanganate ($KMnO_4$) solution instead of $K_2Cr_2O_7$.

Summary. In what two ways does H_2S act? What two groups of metals cannot be precipitated by means of this compound nor by $(NH_4)_2S$ solution? What elements are precipitated as sulphides by $(NH_4)_2S$ but not by H_2S? Which sulphide is white?

Sulphur Dioxide (SO_2), *Sulphurous Acid* (H_2SO_3).

179. Burn a small piece of sulphur and note the odor of the gas formed. In a small porcelain crucible, strongly heat a small piece of iron pyrites (FeS_2) and note the odor.

180. By means of a deflagrating spoon, burn a small piece of sulphur in a 500-cc. flask containing about 20 cc. of water. Cork the flask and shake. Test the action of the water on litmus paper. What has been formed and is now in solution in the water?

181. In a test tube heat a small piece of metallic copper with a few cubic centimeters of concentrated H_2SO_4. What gas is evolved? Repeat, using a small piece of charcoal (C) instead of the copper.

What sort of an action have Cu and C on hot H_2SO_4?

182. For generating SO_2 arrange an apparatus similar to that used for the generation of chlorine (Fig. 11,

page 36). Place about 25 gms. of copper turnings in the flask and add about 30 cc. of concentrated H_2SO_4.

Gently warm the flask and when the gas (SO_2) begins to be evolved in a regular stream, collect one or two bottles by displacement of air and cover with glass plates.

Now prepare an aqueous solution of the gas by passing the latter through about 50 cc. of water in a 100-cc. flask, until the water is saturated.

183. Into one of the bottles of SO_2 prepared above thrust a burning splinter. What happens? Is the gas a supporter or a non-supporter of combustion? Does it burn? Introduce a piece of wet blue litmus paper into one of the bottles of the gas. Dip a piece of blue litmus paper into the aqueous solution of SO_2. What sort of a reaction do you get with the litmus? What is formed by the combination of SO_2 and water?

184. In separate test tubes try the action of the sulphurous acid (H_2SO_3) made in Exp. 182 on solutions of the following substances: potassium permanganate ($KMnO_4$), copper sulphate ($CuSO_4$), potassium dichromate ($K_2Cr_2O_7$), litmus, indigo, and cochineal.

What sort of substances are bleached by sulphurous acid? What element have we previously studied which acts in the same way?

Sulphur trioxide (SO_3), *Sulphuric acid* (H_2SO_4).

185. To prepare H_2SO_4 by the "lead chamber" process, construct the apparatus shown in Fig. 26. Water is boiled in one of the small flasks, NO generated in another, and SO_2 in another. The steam, SO_2 and NO are conducted into the large flask where they come to-

gether with the formation of H_2SO_4. It is not necessary to continue the generation of NO for any length of time inasmuch as little is lost. Air should be blown from time to time through the rubber tube shown in the illustration.

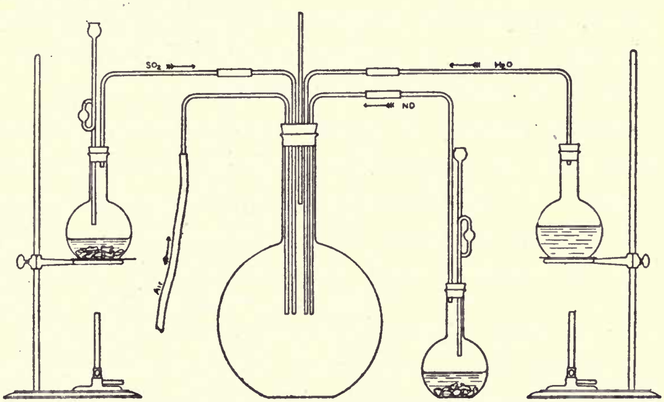


FIG. 26.

Discontinue the production of steam for a moment and notice the formation of "chamber crystals" on the inside walls of the flask. What is the composition of these crystals?

If air is not blown into the flask for a few moments, the contents will become colorless. Then, by blowing air into the apparatus, the brown color of NO_2 is produced.

After running the experiment for some moments, disconnect the apparatus and reserve the H_2SO_4 which has been formed for use in Exp. 186.

186. Try the action of dilute H_2SO_4 from the reagent bottle on solutions of the following substances: barium chloride ($BaCl_2$), strontium chloride ($SrCl_2$), calcium chloride ($CaCl_2$), sodium chloride (NaCl) and lead acetate

($Pb(C_2H_3O_2)_2$). Which metals form insoluble sulphates? Repeat the tests, using the H_2SO_4 prepared in Exp. 185.

187. To a few cubic centimeters of a saturated solution of sugar, in a large beaker, add a few cubic centimeters of concentrated H_2SO_4. What happens?

To a small splinter of wood in a beaker or on a watch glass add a few cubic centimeters of concentrated H_2SO_4. Is the action similar to that with sugar?

188. By means of a graduated cylinder carefully measure 36 cc. of water and pour it into a large dry beaker. Dry the graduate as well as possible and carefully measure out 53 cc. of concentrated H_2SO_4. Slowly pour the acid into the water in a fine stream. Does the beaker become hot? Why? Allow the mixture to cool; then carefully measure its volume. Has there been a contraction or an expansion? What has caused it? (Pour the diluted acid into the large stock bottle labeled "Dilute H_2SO_4.")

189. Place one or two drops of concentrated H_2SO_4 in a clean dry evaporating dish and heat strongly. What happens? (Avoid breathing the fumes.)

190. Make a mixture of powdered $BaSO_4$ and Na_2CO_3; place the mixture on a piece of charcoal and heat strongly with the blowpipe flame. When cold, place the fused mass on a clean silver coin and add a drop or two of water. Does the coin become stained? Why?

Repeat the experiment, using some other sulphate.

191. In separate test tubes try the action of $BaCl_2$ solution on solutions of sodium sulphate (Na_2SO_4), copper sulphate ($CuSO_4$), and magnesium sulphate ($MgSO_4$). Does $BaCl_2$ react the same with soluble sulphates as with H_2SO_4?

Summary. How many series of salts has H_2SO_4? (See Exp. 116.) Write the structural formula for H_2SO_4. What is the test for sulphuric acid and soluble sulphates? For insoluble sulphates? For a sulphide? For free sulphur?

What is pyro-sulphuric acid? Why is it a strong chemical?

Thio-sulphuric Acid ($H_2S_2O_3$).

192. To about 50 cc. of sodium sulphite (Na_2SO_3) solution in a beaker add about 5 gms. of flowers of sulphur and boil for a few minutes. Filter; to a portion of the clear filtrate add a few drops of concentrated H_2SO_4 and allow to stand for a time. To a second portion add a little tincture of iodine.

In separate test tubes try the action of a few drops of concentrated H_2SO_4 and a few drops of iodine solution on a solution of sodium sulphite (Na_2SO_3). Do these tests give the same results as those performed previously?

193. To a solution of $AgNO_3$ add $Na_2S_2O_3$ solution, a drop at a time, until the precipitate at first formed redissolves.

194. Prepare AgCl by adding an NaCl solution to a few cubic centimeters of a solution of $AgNU_3$. Try the action of $Na_2S_2O_3$ on the precipitate. What commercial applications are made of this reaction?

195. In a test tube try the action of $Na_2S_2O_3$ solution on a few cubic centimeters of a solution of $KMnO_4$.

Repeat, using iodine solution instead of $KMnO_4$. What other oxygen acid of sulphur is produced by this latter reaction?

Summary. What common use is made of $Na_2S_2O_3$? What are the common, though incorrect, names for this

compound? Why is the salt called a "thio-sulphate"? If it were possible to make such a compound as a "thio-nitrate," what would be the formula for it?

Problems. (a) What volume of H_2S gas, at 25° and 860 mm., can be obtained by the action of an excess of acid on 3800 gms. of 72% Sb_2S_3?

(b) By roasting 20 tons of 90% ZnS ore and using the by-product in the manufacture of H_2SO_4, what volume of 45% H_2SO_4 can theoretically be obtained?

(c) What weight of precipitated sulphur can be obtained by treating 600 gms. of $Na_2S_2O_3$, dissolved in water, with excess of H_2SO_4?

(d) What weight of gas (0° and 760 mm.) will be obtained by heating together 36 gms. of pure carbon and an excess of concentrated H_2SO_4?

CHAPTER X.

CARBON (C; 12).

196. Place a small piece of wood in an iron crucible and cover with a layer of sand. Heat with the full force of the Bunsen burner until gas no longer comes from the crucible and burns. Allow to cool. Examine the contents of the crucible. What is the composition of wood?

197. Place about 5 gms. of cane sugar in a porcelain evaporating dish and heat gently until there is no further change in the appearance of the material in the dish. What are the chief products formed when sugar is heated?

198. Turn off the air supply on a Bunsen burner so that it burns with a luminous flame. Hold a piece of cold porcelain (crucible, evaporating dish or mortar) in this flame and observe the black deposit.

Compare the products formed in these three experiments. Compare them with the bone black on the side shelf. Why do we not make bone black in the laboratory?

199. Fill a hard glass tube with small pieces of soft coal. Connect a delivery tube as shown in Fig. 6, page 15. Heat the tube strongly and collect the gas evolved in bottles by displacement of water. Examine this gas. Will it burn? Has it any odor?

Examine the residue in the tube and compare it with the other varieties of carbon formed in the preceding experiments. Notice the water over which the gas was collected.

200. Heat a bit of charcoal on platinum foil. Likewise heat a bit of graphite on platinum foil. Do both substances burn? Which is the more stable form of carbon? Name another stable variety of carbon.

201. Add about a gram of powdered bone black to 15 cc. of an indigo solution. Boil for a few minutes. Filter and examine the filtrate.

Repeat, using litmus solution instead of indigo.

202. Into a small flask containing 15 or 20 cc. of H_2S solution introduce about 2 gms. of powdered bone black. Cork the flask and shake for several minutes. After standing for 15 minutes, filter the contents and test a portion of the clear filtrate for H_2S by adding a few drops of lead acetate ($Pb(C_2H_3O_2)_2$) solution.

What commercial use is made of bone black?

Approximate Analysis of Coal.

(Quantitative.)

203. Determination of Volatile Matter. Carefully weigh a clean dry porcelain crucible and cover. Introduce about 2 gms. of powdered coal into the crucible and again weigh carefully. The difference in weight represents the weight of the coal taken.

Place the crucible, covered, on a triangle on a ring-stand and heat strongly until gases no longer come from the crucible and burn. Allow to cool; then weigh carefully.

Calculate the loss in weight of the coal. This loss in weight represents volatile matter in the coal. Express your result as "percentage of volatile matter."

Examine the residue in the crucible. What is the nature of it?

Determination of Ash. Carefully weigh a clean dry porcelain crucible without the cover. Introduce about 2 gms. of powdered coal and again weigh accurately. Place the crucible on a triangle and cover with a crucible cover. Apply heat with the crucible covered until gases no longer come from the crucible and burn. Then remove the cover and place the crucible in an inclined position on the triangle so that air may enter freely. Heat with the full force of the Bunsen burner until all carbon is burned and the ash in the crucible is white or gray in color.

Allow the crucible to cool; then weigh. Calculate the percentage of ash in the coal.

Assuming that the determinations of ash and volatile matter are accurate, what is the percentage of carbon in the sample of coal used? Record the number of the sample of coal analyzed.

Carbon Monoxide (CO).

204. Prepare carbon monoxide (CO) by heating together 15 gms. of oxalic acid ($H_2C_2O_4$) and 50 cc. of concentrated H_2SO_4 in an apparatus as shown in Fig. 27. The wash bottle should contain a concentrated solution of NaOH.

Collect several bottles of the gas over water. Ascertain if it will burn or support combustion. Add a few cubic centimeters of lime water or baryta water to the bottle tested; cover and shake.

205. Disconnect the apparatus at point *a* and in place of the delivery tube connect a piece of hard glass tubing containing a little black copper oxide. While continuing the generation of CO, strongly heat the copper oxide

in the glass tube. What happens? Pass the gas coming from the apparatus into lime water.

206. Place a few crystals of oxalic acid in a test tube and add a little concentrated H_2SO_4. Heat until reaction takes place. Test the gas evolved (1) for CO, by bringing the mouth of the test tube to a flame, and (2) for CO_2 by holding a glass rod with a drop of lime water at the end in the mouth of the tube.

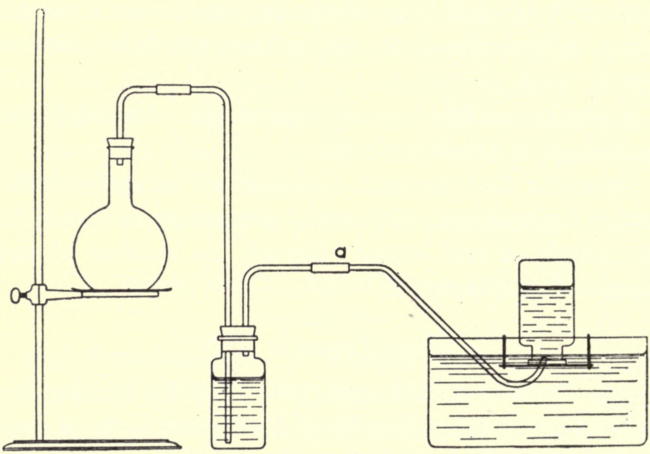


FIG. 27.

207. Arrange an apparatus as shown in Fig. 28, consisting of CO_2 generator, wash bottle and hard glass tube. Partially fill the hard glass tube with powdered zinc. Then generate CO_2 in the flask by means of marble and HCl, and strongly heat the hard glass tube containing the zinc. Test the gas coming from the end of the hard glass tube to ascertain if it will burn.

208. Introduce an intimate mixture of about two parts by weight of powdered $CaCO_3$ and one part of

powdered zinc into a hard glass test tube or a piece of hard glass tubing closed at one end. Arrange a delivery tube as shown in Fig. 6, page 15. Strongly ignite and then collect one or two bottles of the gas which is evolved. Test the gas. What is it?

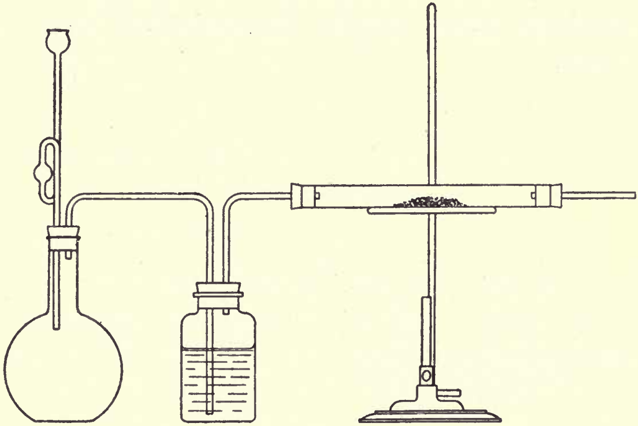


FIG. 28.

Carbon Dioxide (CO_2), *Carbonic Acid* (H_2CO_3).

209. By means of a piece of glass tubing, blow through a little lime water in a beaker for several minutes. What causes the change? Compare with Exp. 122, page 59.

210. Place a small piece of marble ($CaCO_3$) in a test tube and add HCl. Test the gas evolved by holding a glass rod with a drop of lime water at the end in the mouth of the tube.

211. Arrange an apparatus consisting of a CO_2 generator and wash bottle nearly filled with water as shown in Fig. 29. Place a few lumps of marble in the flask, cover with water and add concentrated HCl through

the thistle tube to produce a brisk evolution of the gas. Collect several bottles of CO_2 over water. Cover with glass plates and reserve for use in Exps. 215 and 216.

212. Change the delivery tube at *a* as shown by the dotted line and pass CO_2 through lime water until there is no further change. Be careful to notice all changes.

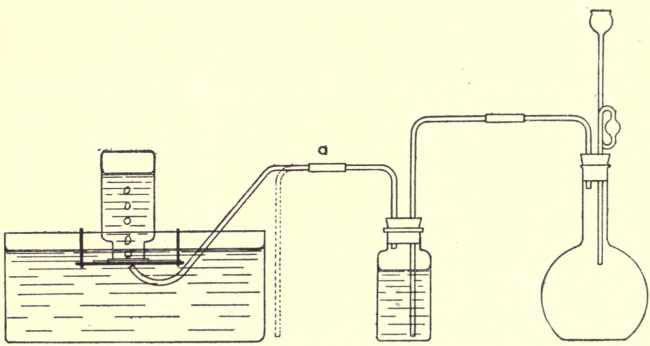


FIG. 29.

213. Pass CO_2 through 100 cc. of water for several minutes. Taste the water. Try its action towards litmus paper. What is in solution in the water?

214. Pass CO_2 through about 25 cc. of dilute NaOH solution until the latter is saturated. What is formed? Add dilute HCl to the solution. Does this prove the nature of the compound in solution? Compare with Exp. 210.

215. Into one of the bottles of CO_2 collected in Exp. 211 introduce a piece of wet litmus paper. To another add a few drops of baryta or lime water. Plunge a

burning splinter into another bottle of the gas. Into a fourth bottle introduce, by means of forceps, a piece of burning magnesium ribbon which has been previously cleaned with sand paper.

216. Ignite a few drops of benzene on a watch glass. Pour CO_2 from a bottle onto the burning benzene. What happens? What commercial application is made of this reaction?

Determination of the Weight of a Liter of Carbon Dioxide.

(Quantitative.)

217. This experiment is carried out in exactly the same manner as the determination of the weight of a liter of chlorine (Exp. 63, page 38). The CO_2 may be generated by the action of HCl on $CaCO_3$ and must be passed through a wash bottle containing water, and a drying bottle containing concentrated H_2SO_4. Why are the wash bottle and the drying bottle necessary?

Carbon Disulphide (CS_2).

218. Place a few drops of CS_2 on the hand and blow across it. Note the color and odor of the liquid. Will it mix with water?

219. Pour a few drops of CS_2 into a porcelain dish. Heat a glass rod to redness and hold over the dish just above the liquid. Note the products formed when CS_2 burns. How many products can you identify? Write several equations to represent the burning of CS_2 with varying amounts of oxygen.

Determination of Specific Gravity of Carbon Disulphide.

220. For this experiment a small flask with a tightly fitting cork or rubber stopper may be employed. With a triangular file make a scratch about half way up the neck of the flask.

Carefully clean the flask and stopper and when both are thoroughly dry, insert the stopper in the flask and weigh. Let this weight of the empty flask be represented by E. Now fill the flask to the mark on the neck with distilled water, cork and weigh. Let this weight be represented by W. Empty the flask and rinse about four times with small amounts of alcohol and thoroughly dry by means of a blast of air. Fill the flask to the mark on the neck with the sample of CS_2 to be determined, cork and weigh. Let this weight be represented by L.

$W - E$ equals the weight of the water and $L - E$ then equals the weight of an equivalent volume of the CS_2 being determined. *The specific gravity of a substance is the relation of the weight of a given volume of the substance as compared with the weight of an equal volume of water*, and inasmuch as the unit volume of water, 1 cc., weighs 1 gram, *the specific gravity of any substance is numerically the weight of a cubic centimeter of that substance expressed in grams.* From this

$$\text{Specific Gravity} = \frac{L - E}{W - E}.$$

Problems. (a) How many grams of 95% $CaCO_3$ will be required to produce 1800 liters of CO_2 at standard conditions?

(b) What volume of oxygen will be required to completely

burn 780 liters of CO? What volume of CO_2 will be formed (0° and 760 mm)?

(c) How many cubic centimeters of CS_2 can be theoretically produced from 120 gms. of sulphur?

(d) If 284 cc. of CS_2 are volatilized at 35° and 722 mm. pressure, what volume of gas will be formed?

Cyanogen and the Cyanides.

221. Fit a test tube with a one-hole stopper carrying a short piece of glass tubing drawn to a point. Into

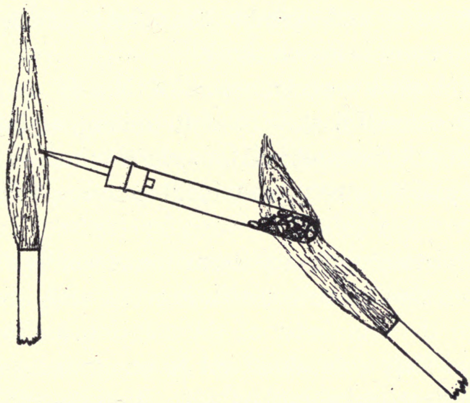


FIG. 30.

the tube introduce a few grams of mercuric cyanide ($Hg(CN)_2$) and heat gently, letting the outlet tube touch a second flame. (Fig. 30.) Do not breathe the gas. Why? (Hood.)

To what is the gas cyanogen, C_2N_2, equivalent chemically?

222. Add a solution of potassium cyanide (KCN), a drop at a time, until in excess, to a solution of silver nitrate ($AgNO_3$).

223. Add potassium sulphocyanate solution (KCNS) to a little dilute $FeCl_3$ solution.

224. Mix a few drops each of KCN solution and $(NH_4)_2S_x$ on a watch glass and cautiously evaporate to a small volume. Test the resulting solution by adding a drop of $FeCl_3$ solution. Compare with previous experiment.

225. In a porcelain crucible heat a small piece of KCN with about twice as much lead oxide (PbO). (HOOD.) When entirely melted, allow to cool; then extract with water and examine the solid product formed. What compound is in solution?

226. Mix about 15 cc. each of NaOH and $FeSO_4$ solution in a small flask. Heat to boiling, add about 15 cc. of KCN solution and boil for several minutes. Dilute with an equal volume of water, filter and add HCl until neutral.

In separate test tubes try the action of small portions of the solution thus formed on solutions of $CuSO_4$ and $FeCl_3$.

227. To the remainder of the solution formed in the first part of Exp. 226, add about 20 cc. of strong bromine water and heat to boiling. Cool. Test a small portion of $FeCl_3$ solution with the solution thus formed. Also try the action of the solution on $CuSO_4$ solution.

228. Test the action of a solution of potassium ferrocyanide ($K_4Fe(CN)_6$) on solutions of (1) $FeCl_3$ and (2) $FeSO_4$. Likewise try the action of a solution of potassium ferricyanide ($K_3Fe(CN)_6$) on solutions of $FeCl_3$ and $FeSO_4$.

Express the results of these four tests in the form of a table, stating whether or not a precipitate is formed and also the color produced.

Organic Chemistry.

229. **Methane (CH_4).** Into a hard glass tube, sealed at one end, introduce an intimate mixture of equal parts of fused sodium acetate and dry soda lime. Arrange a delivery tube as shown in Fig. 6, page 15.

Strongly ignite the tube and collect the gas evolved by displacement of water. Test the gas with a burning splinter. Has the gas any odor?

230. **Acetylene (C_2H_2).** Treat a few pieces of calcium carbide (CaC_2) with water in a large beaker and ignite the gas which is produced. Why does it burn with a smoky flame? How could you arrange an apparatus to burn the gas with a brilliant smokeless flame?

231. **Fermentation.** In a large flask treat about 25 cc. of molasses with 200 cc. of water. Add a little yeast and stopper the flask loosely with a wad of cotton. Allow it to stand several days, preferably in a warm place.

Warm the flask and contents and test for CO_2 by introducing a glass rod with a drop of lime water or baryta water on the end.

Filter the contents of the flask and distill the clear filtrate (Fig. 8, page 23), collecting only the portion which distills below 90°. Examine this distillate. Notice the odor. What is the compound?

Summary. What is a good definition of "organic" chemistry?

What is a hydrocarbon? What is the name of the most simple series of hydrocarbons? Give general formulas of the more common series.

What is the characteristic group of an alcohol? Of an organic acid? Of an aldehyde? What general name is applied to organic salts?

CHAPTER XI.

SILICON AND BORON.

SILICON (Si; 28).

232. To a few cubic centimeters of sodium silicate (Na_2SiO_3) solution in a test tube add a little concentrated HCl. What happens? Test the solubility of the product formed in both acids and alkalies.

Dilute a few cubic centimeters of Na_2SiO_3 solution with three times its volume of water and add a little concentrated HCl to the mixture. Is there a precipitate formed? Allow the test tube containing the mixture to stand quietly for a time. Does it change in appearance?

233. Try the action of a solution of NH_4Cl on a solution of Na_2SiO_3. Compare the product with that obtained from the first part of Exp. 232. Explain fully and write all equations.

234. In an evaporating dish add concentrated HCl to about 10 cc. of Na_2SiO_3 solution and evaporate to dryness. Treat the residue with a little water. Filter. Examine the residue left on the filter. Is it gelatinous? Why?

Dry the residue by pressing it between pieces of filter paper and save for use in Exps. 235 and 236.

235. In a loop at the end of a piece of platinum wire make a bead of "microcosmic salt" ($NaNH_4HPO_4$) in the same way in which borax beads are made (see Exp. 162).

Introduce a little of the powdered silica (SiO_2) from Exp. 234 into the bead and fuse in the Bunsen flame. Observe the bead both while in a molten condition and after cooling. Is silica soluble in the microcosmic salt bead?

Repeat this bead test with a sample of powdered quartz or sand. Try the test with some insoluble silicate in powdered condition. For what is the bead a good test?

236. Into a test tube introduce a mixture of a little powdered quartz or sand and a little fluorspar (CaF_2). Moisten the mixture with concentrated H_2SO_4.

Heat the mixture gently, at the same time holding in the mouth of the test tube a glass rod with a drop of water on the end.

Repeat the test, using SiO_2 from Exp. 234. Repeat with some insoluble silicate.

237. Make an intimate mixture of one part SiO_2 and five parts dry Na_2CO_3. Place the mixture in an iron crucible, cover and heat strongly. Occasionally raise the cover and note the appearance of the contents. The heating should be continued until the contents of the crucible are in a state of quiet fusion.

Cool, extract the melt with water and filter. What compound does the filtrate contain? Evaporate a portion of the filtrate to dryness and examine the residue. Test another portion with concentrated HCl, and a third portion with NH_4Cl solution. Compare with Exps. 232 and 233.

238. In separate test tubes try the action of Na_2SiO_3 solution on solutions of $CuSO_4$, $BaCl_2$, $ZnSO_4$ and $Pb(C_2H_3O_2)_2$.

Observe the nature of the products. Are these insoluble silicates varieties of glass? Why?

239. Break a clean dry test tube, place the pieces in a clean dry porcelain mortar and grind to a fine powder. (CAUTION. *Protect the eyes.*) Moisten the powder with a few drops of water and then add a drop of phenolphthalein. Explain the phenomenon observed. What are the ingredients of Bohemian glass? What can you say of the solubility of glass?

240. Fluosilicic Acid (H_2SiF_6). Arrange an apparatus as shown in Fig. 31. The delivery tube should dip below the surface of a layer of mercury at the bottom of the cylinder of water. Use a 250-cc. flask. It is very necessary that the flask and delivery tube be thoroughly dry inside, and for this reason the water should not be introduced into the cylinder until the experiment is started.

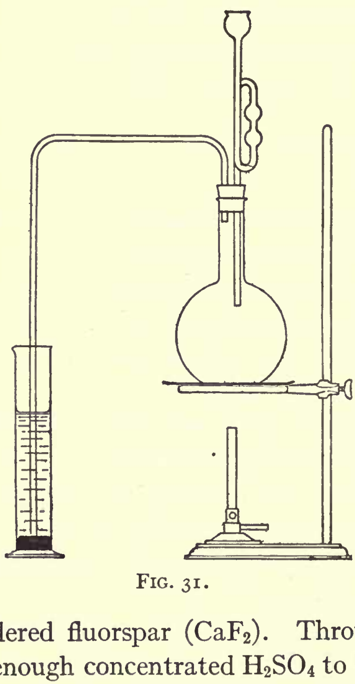


FIG. 31.

Into the flask introduce an intimate mixture of 15 gms. of fine sand or powdered quartz, and 10 gms. of powdered fluorspar (CaF_2). Through the thistle tube add enough concentrated H_2SO_4 to form a thick paste. Agitate the flask to thoroughly mix the contents. Place

the flask in the position shown, letting the delivery tube extend to the bottom of the cylinder. Pour mercury into the latter until the end of delivery tube is submerged, and then nearly fill the cylinder with water.

Gently heat the flask and observe the gas as it bubbles through the water in the cylinder. What is the gelatinous substance formed? Have you ever seen the compound before? Where is the fluosilicic acid?

After the experiment has been running for some time and the cylinder of water contains considerable of the gelatinous precipitate, disconnect the apparatus and filter the liquid in the cylinder.

241. Test the action of the clear filtrate from Exp. 240 with litmus paper. What sort of a compound is in solution?

To a small portion of the filtrate add $BaCl_2$ solution. To the remainder of the filtrate add KCl or KNO_3 solution and allow the mixture to stand for 30 minutes. Filter. Dry the precipitate between pieces of filter paper. Examine carefully. Test a small portion as directed in Exp. 235 and another portion as directed in Exp. 236.

Determination of the Specific Gravity of Sand.

242. Use a flask with a mark on the neck as in Exp. 220. Weigh the flask empty (E). Partially fill with clean dry sand and again weigh (S). Now add water until the flask is filled to the mark on the neck; again weigh (X).

Empty the flask, rinse and completely fill with water alone to the mark on the neck. Weigh (W).

The weight of substance taken equals $S - E$. The weight of water needed to fill the flask containing the substance equals $X - S$. The weight of water needed

to completely fill the flask equals $W - E$. The difference between the weight of water in the two cases is $(W - E) - (X - S)$ and equals the weight of a volume of water equal to the volume of the substance used. Therefore,

$$\text{Specific Gravity} = \frac{S - E}{(W - E) - (X - S)}.$$

BORON (B; 11).

243. In a beaker dissolve 10 gms. of borax ($Na_2B_4O_7$) in 40 cc. of boiling water and to the solution add 6 cc. of concentrated HCl. Allow the solution to cool. What compound crystallizes out?

Filter and wash the crystalline mass with a few cubic centimeters of distilled water. Dry by pressing between pieces of filter paper.

Is boric acid soluble in water? If so, why does it crystallize out from the solution prepared above?

244. Make a solution of boric acid in water. Dip a piece of turmeric paper into the solution. Does the paper change in color? Dry the paper by holding for a few moments high above a burner flame or by putting it around the neck of a flask in which water is being boiled. What is the color of the paper upon drying? What effect does a drop of NH_4OH produce on the color?

245. To a few crystals of boric acid in an evaporating dish add a few cubic centimeters of alcohol. Ignite the alcohol and observe the color of the flame until the alcohol is entirely burned. Is any characteristic color imparted to the flame by the boric acid? Explain.

246. In separate test tubes, add a solution of $Na_2B_4O_7$

to solutions of $MnSO_4$, $CuSO_4$, and $CaCl_2$. What is the nature of the precipitates?

247. Make a borax bead (see Exp. 162) and hold in the flame until perfectly clear. Allow to cool; then separate the bead from the wire and introduce it into a test tube half full of water. Does the bead dissolve? How does the composition of the borax bead differ from that of ordinary borax?

248. Repeat Exps. 244 and 245, using borax instead of boric acid, and adding in each case a few drops of concentrated H_2SO_4. How do the results compare with those obtained in Exps. 244 and 245? Why is it necessary to add H_2SO_4 in making the tests with borates, whereas in the experiments with boric acid H_2SO_4 was not necessary?

Problems. (a) To make 15 kilos of a 21% solution of sodium silicate, what weight of 98% pure sand and what weight of pure dry sodium carbonate will be necessary?

(b) If the efficiency of the electric furnace process for the manufacture of carborundum is 83%, what will be the weight of the charge necessary to produce 200 kilos of carborundum?

(c) If 75 liters of silicon tetrafluoride at 33° and 740 mm. pressure are passed through water, what weight of dried silica and how much 18% fluosilicic acid will be obtained?

(d) From 2 tons of crystallized borax what weight of pure dry boric acid can be produced?

(e) What volume of boron trichloride can theoretically be obtained from 250 gms. of pure boron trioxide?

CHAPTER XII.

PHOSPHORUS, ARSENIC, ANTIMONY AND BISMUTH.

PHOSPHORUS (P; 31).

249. Dry a small piece of phosphorus by means of filter paper. Using the pincers, place the piece of phosphorus on a dry iron dish or piece of asbestos board and allow to stand in the air until it ignites.

250. By means of a deflagrating spoon, burn a small piece of phosphorus in a wide-mouth bottle. When combustion is complete, withdraw the spoon and cover the bottle to prevent the escape of the white fumes. Add about 20 cc. of water to the contents of the bottle and shake. Test the reaction of the water towards litmus paper. (Reserve the solution for use in another experiment.)

251. Dissolve a piece of phosphorus about the size of a grain of wheat in a few cubic centimeters of CS_2. Pour the solution on a piece of filter paper and allow the CS_2 to evaporate. (*Do not get the solution on the hands or clothing.*) Why does the phosphorus take fire so readily when the CS_2 has evaporated?

252. To a small piece of phosphorus in a test tube add 3 or 4 cc. of concentrated HNO_3 and boil. What becomes of the phosphorus? (Save the solution for use in another experiment.)

253. Red Phosphorus. Carefully dry a piece of phosphorus about half the size of a pea and introduce into a

test tube. Stopper the test tube tightly with an ordinary cork. Using a test tube holder, hold the tube above a burner with the flame turned low, at such a distance that the phosphorus boils slightly. (HOOD.) Continue to heat in this way until there is a decided change in the appearance of the phosphorus. (CAUTION.)

Allow the tube to cool thoroughly. Then test the solubility of the product in CS_2.

Mention several ways in which red phosphorus differs from yellow phosphorus.

254. Heat a bit of red phosphorus in an evaporating dish. What happens? What compound is formed?

255. **Phosphorus and the Halogens.** Under the hood, place a crystal of iodine on a small dry piece of yellow phosphorus. Allow to stand for a moment. Does any action take place? What compound is formed?

256. Place a little red phosphorus in a dry test tube standing in a test-tube rack or in a bottle under the hood. (*Do not hold the test tube in the hand.*) Into a second test tube pour a little bromine. Now quickly pour the bromine into the test tube containing the red phosphorus. (CAUTION.)

What can you say as to the affinity of phosphorus for the halogens? Make a list of names and formulas of all the halogen compounds of phosphorus which have been studied or formed in experiments up to the present time and give the number of the experiment involved in each case.

257. **Phosphine (PH_3).** Acidify a beaker of water with HCl. Place under the hood and then introduce a piece of calcium phosphide (Ca_3P_2). Allow to stand

for several minutes. Describe all results and write all equations involved.

258. Under the hood arrange an apparatus as shown in Fig. 32. Introduce into the flask 25 cc. of strong NaOH solution and five or six small pieces of yellow phosphorus. Close all joints tightly. (*Do not proceed*

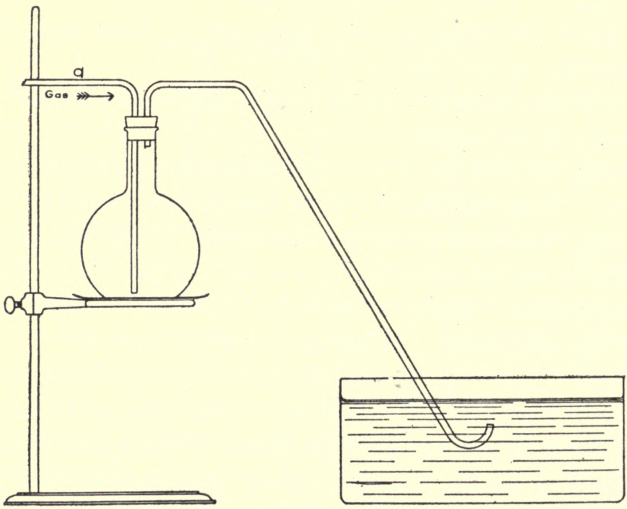


FIG. 32.

further until the apparatus has been approved by the instructor.) Connect tube *a* with a gas supply and pass gas through the apparatus to displace all air. Then shut off the gas and apply heat carefully to the flask. (*Keep the hands away from the flask after heat is applied.*) Phosphine comes from the exit tube and burns as it strikes the air. Note the white rings formed when the phosphine burns. What is the composition of the white fumes?

Continue the experiment until PH_3 no longer comes from the apparatus. Then discontinue the heat and immediately turn on the stream of gas through *a* to drive all phosphine from the apparatus. After this is done, cool the flask by introducing 100 cc. of water into it. (Pour the contents of the flask into the large bottle labeled "Hypophosphite Solution.")

(CAUTION! *This is a dangerous experiment and should be performed with the greatest care.*)

Is there more than one compound of phosphorus and hydrogen? Describe them all.

259. Oxides of Phosphorus. How many oxides of phosphorus are there? Which of the oxides have you already made? Expose a small amount of phosphorus pentoxide (P_2O_5) to the air. What happens? Drop a small amount of the dry oxide into water. What do you notice?

From these two tests what do you conclude as to the affinity of P_2O_5 for water?

Acids of Phosphorus.

260. Ortho-phosphoric Acid (H_3PO_4). In a test tube try the action of $AgNO_3$ solution on a solution of ordinary sodium phosphate (di-sodium phosphate, Na_2HPO_4).

261. To about 1 cc. of Na_2HPO_4 solution in a test tube add about an equal volume of concentrated HNO_3 and then a like volume of ammonium molybdate ($(NH_4)_2MoO_4$) solution. If no precipitate is formed, warm gently for a time.

Repeat the test, using the solution formed in Exp. 252 instead of the Na_2HPO_4 solution.

The yellow precipitate formed is "ammonium phospho-molybdate." This is the best test for phosphoric acid.

262. To a few cubic centimeters of a solution of Na_2HPO_4 in a test tube add solutions of NH_4Cl, NH_4OH and $MgSO_4$. What is the compound formed? Why is this compound of considerable importance in analytical chemistry?

263. When the yellow precipitate formed in Exp. 261 has settled, carefully decant as much as possible of the supernatant liquid. Then add strong NH_4OH to dissolve the yellow residue. To the solution thus formed add solutions of NH_4Cl and $MgSO_4$. Compare the precipitate with that formed in Exp. 262.

264. Try the action of a solution of sodium phosphate on solutions of copper and calcium.

265. Pyrophosphoric Acid ($H_4P_2O_7$). Prepare sodium pyrophosphate ($Na_4P_2O_7$) by strongly heating a few crystals of di-sodium phosphate (Na_2HPO_4) on a piece of platinum foil. Dissolve the fused salt in a little cold water.

Test a portion of the solution with $AgNO_3$ solution.

266. Test a few cubic centimeters of a pyrophosphate solution with HNO_3 and ammonium molybdate as directed in Exp. 261. Is a precipitate formed? Why?

Repeat the test, boiling the solution with the HNO_3 for a moment before adding the ammonium molybdate. Does a precipitate form now? Why is it necessary to boil the solution?

How can pyrophosphoric acid be formed directly from orthophosphoric acid?

267. Metaphosphoric Acid (HPO_3). Fuse a few crystals of microcosmic salt (sodium ammonium hydrogen

phosphate, $NaNH_4HPO_4$) on a piece of platinum foil or in a loop at the end of a platinum wire. Notice the odor of the gas which is given off. Heat until effervescence ceases. What is the composition of the remaining salt? What is the name of the compound?

268. Dissolve the fused salt prepared in Exp. 267 in a little cold water and test a small portion with a solution of $AgNO_3$. To a second portion add a few drops of acetic acid and then a little egg albumen solution. Why is the acid necessary?

Try these two tests on the solution formed in Exp. 250. Which of the phosphoric acids is formed when P_2O_5 is dissolved in cold water? How can metaphosphoric acid be formed directly from orthophosphoric acid or from pyrophosphoric acid?

269. Phosphorous Acid (H_3PO_3). Under the hood, pour a few cubic centimeters of phosphorus trichloride (PCl_3) into a flask containing 30 cc. of water. Agitate the flask to hasten reaction. Notice the fumes which are evolved. Test their action towards litmus paper. What are the fumes?

Transfer the solution in the flask to an evaporating dish and evaporate to half the volume. Why? Allow the resulting syrupy liquid to cool; then dilute with about 10 cc. of distilled water.

Test a small portion of the solution thus formed with $AgNO_3$ solution. Warm gently and notice the precipitate. How does the $AgNO_3$ test for H_3PO_3 differ from that with H_3PO_4, $H_4P_2O_7$ and HPO_3?

270. Place the remainder of the phosphorous acid solution in an evaporating dish and evaporate to dryness. Note all phenomena and explain fully.

271. Hypophosphorous Acid (H_3PO_2). Place three or four pieces of yellow phosphorus in 25 cc. of baryta solution in an evaporating dish under the hood. Place the dish on a ring stand and apply heat to bring about reaction (see Exp. 258). When phosphine is no longer evolved, cool and filter the solution. (*It is well to burn the filter paper and residue, as it may contain small pieces of phosphorus.*)

Pass CO_2 through the clean filtrate to precipitate the excess of barium in the solution. Filter and evaporate the filtrate to syrupy consistency. Upon cooling, barium hypophosphite ($Ba(H_2PO_2)_2$) should crystallize out.

272. Dissolve the crystals in a little distilled water, acidify a portion with $HC_2H_3O_2$ and add $AgNO_3$ solution. Watch carefully while performing this test.

Summary. By what test can orthophosphoric acid and the orthophosphates be distinguished from the pyro and meta acids and their salts? By what tests can pyrophosphoric acid and its compounds be distinguished from the ortho and meta acids and their salts? What tests can be used to distinguish meta phosphoric acid and its salts from the ortho and pyro acids and their compounds?

Show by equations how ortho, pyro and meta phosphoric acids can be made from P_2O_5 and water. Which of these acids is actually made when P_2O_5 is dissolved in cold water?

Show, by equations, all changes which take place when H_3PO_4 is heated. Which acid of phosphorus is the most stable towards heat? Which two acids of phosphorus are the least stable when heated?

Problems. (a) What volume of a 65% solution of phosphoric acid can be obtained as a by-product in the manufacture of 60 kilos of potassium hypophosphite?

(b) From two liters of 85% phosphoric acid, what weight of metaphosphoric acid can be obtained?

(c) How much pure yellow phosphorus will be necessary in the preparation of 2 liters of phosphorus trichloride?

(d) If 200 liters of phosphine, at 180° and 760 mm. pressure, are burned in an inclosed chamber and the fumes treated with water, what volume of a 12% solution of phosphoric acid can be obtained?

(e) From 200 lbs. of bone ash, running 94% tricalcium phosphate, what weight of phosphorus can be produced?

ARSENIC (As; 75).

273. In a hard glass test tube strongly ignite a small piece of arsenic. Likewise heat a little of a mixture of arsenic trioxide (As_2O_3) and powdered charcoal. Notice the sublimate in each case. What is the composition of the sublimate?

274. Heat a small piece of arsenic on a piece of charcoal with the oxidizing blowpipe flame. Notice the white ring which forms around the arsenic and at some distance from the latter.

275. Treat a little powdered arsenic with concentrated HNO_3 and heat to boiling. What is formed?

Treat a little powdered arsenic with aqua regia. Does the arsenic dissolve?

Try the solubility of arsenic in concentrated HCl.

276. Test the solubility of small amounts of arsenic trioxide (As_2O_3) in water, in concentrated HCl, in HNO_3 and in a solution of NaOH.

277. Pass H_2S through an aqueous solution of As_2O_3. Observe carefully.

Pass H_2S through an aqueous solution of As_2O_3 after first adding a few cubic centimeters of HCl. Why is there a difference in these two tests? Allow the precipitate of As_2S_3 to settle; then decant as much as possible of the supernatant liquid. Treat the precipitate with a few cubic centimeters of $(NH_4)_2S$ solution. To the solution thus formed add concentrated HCl until acid to litmus paper. Note all changes and write all equations.

278. In separate test tubes try the action of (1) $AgNO_3$ solution and (2) $CuSO_4$ solution on a solution of an arsenite. Note the color of each of the precipitates.

Likewise try the action of an arsenate solution with solutions of $AgNO_3$ and $CuSO_4$. Does an arsenate give the same colors as an arsenite?

279. Dissolve a small amount of As_2O_3 in NaOH, neutralize a small portion with acetic acid and test with $AgNO_3$ solution. To the remainder of the solution add concentrated HNO_3 until strongly acid and then heat to boiling. Cool under the faucet. Add NaOH until alkaline and then acetic acid until slightly acid. Test a portion with $AgNO_3$ solution. What compound have you made in this experiment? Write all equations.

280. Try the action of magnesia mixture ($NH_4OH + NH_4Cl + MgSO_4$) on a solution of an arsenate. What other acid group gives a similar test with magnesia mixture?

Try the action of HNO_3 and ammonium molybdate solution on a solution of an arsenate. Is a precipitate formed? Heat to boiling and then allow to stand quietly for a few moments. How does this test differ from that with a phosphate?

281. Try the action of H_2S on a solution of an arsenite which has been acidified with HCl.

Likewise try the action of H_2S on an arsenate solution which has been acidified with HCl. Is there a difference in these two tests? Heat the arsenate solution to boiling and continue to pass a stream of H_2S through the solution for several minutes. Explain fully and write all equations.

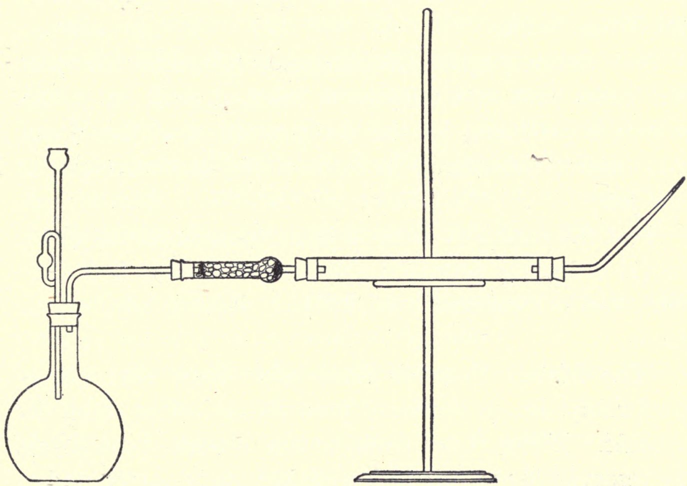


FIG. 33.

282. **Marsh Test for Arsenic.** Arrange an apparatus consisting of a hydrogen generator, drying tube, filled with dry pieces of $CaCl_2$, hard glass tube and exit tube drawn to a fine point, as shown in Fig. 33.

Generate hydrogen by the action of HCl or dilute H_2SO_4 on pure zinc. Test the gas coming from the exit tube and as soon as all air has been driven from the

apparatus, light the jet after first wrapping a towel about the generator.

Through the thistle tube now add a few cubic centimeters of the solution to be tested for arsenic (use any arsenic solution in this experiment) and notice the change which almost immediately is produced in the color of the flame.

Collect several arsenic spots by holding pieces of cold porcelain for a moment in the arsenic flame. Save these for future tests.

Now strongly ignite the hard glass tube through which the gases pass and notice the black deposit of arsenic which is produced by the decomposition of the arsine. Also notice the change in color of the flame burning at the jet.

Test the solubility of the arsenic spots produced above in (1) a freshly prepared solution of sodium hypochlorite, and (2) concentrated HNO_3. Record all observations.

(The Marsh Test for Antimony (Exp. 287) should preferably be performed immediately after that for arsenic. If this is not done, several arsenic spots should be reserved for comparison with the antimony spots.)

ANTIMONY (Sb; 85).

283. Strongly ignite a small piece of antimony in a hard glass test tube. Is a sublimate formed?

Melt a little antimony before the blowpipe on a piece of charcoal and drop the molten globule upon a piece of manilla paper spread out on the desk.

284. In a test tube treat a little powdered antimony

with concentrated HNO_3. Compare with the corresponding experiment with arsenic.

285. Pour a few cubic centimeters of antimony trichloride ($SbCl_3$) solution into a beaker of water. What is the precipitate formed? Divide into two portions and treat one with concentrated HCl. Treat the other portion with a saturated solution of NaCl. Can you explain these tests?

286. Dilute a little $SbCl_3$ solution with an equal volume of water and pass H_2S through the mixture. Test the solubility of a portion of the precipitate in concentrated HCl. Test a second portion with a solution of $(NH_4)_2S$ and warm if necessary. To the solution in $(NH_4)_2S$ now add concentrated HCl until the solution is barely acid. Compare the precipitate of sulphide thus formed with the precipitate first obtained with $SbCl_3$. Are they the same?

Do the sulphides of arsenic and antimony behave alike when treated with ammonium sulphide?

287. Marsh Test for Antimony. Perform the Marsh test for antimony in exactly the same manner as for arsenic. Compare the arsenic and antimony spots. Compare the deposits produced when the hard glass tube is heated. Which comes nearer the flame? Do HNO_3 and NaClO affect the antimony spots the same as the arsenic spots? Write all equations.

BISMUTH (Bi; 208).

288. Make a mixture of a little bismuth trioxide (Bi_2O_3), and dry Na_2CO_3 and heat on a piece of charcoal with the reducing flame of the blowpipe. Note the

globule of metal thus formed. How does it compare with lead?

289. Test the solubility of small particles of bismuth in (1) HCl, (2) aqua regia, and (3) concentrated HNO_3. Write all equations. How does the action of HNO_3 on bismuth compare with its action on the other members of this group?

290. Carefully weigh out 4 gms. of bismuth, 2 gms. of lead and 2 gms. of tin. Place the metals together in a small beaker, cover with water and heat until the water boils. Do the metals melt?

Transfer the metals to an iron crucible and heat strongly to completely fuse the mixture. Allow to cool; then place the alloy in a beaker of water as before and heat to boiling. What is the melting point of the alloy? What is the melting point of each of the metals?

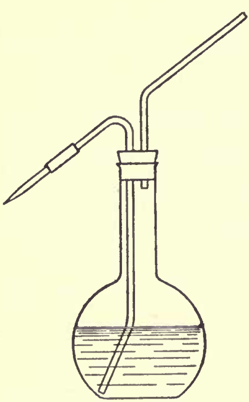


FIG. 34.

291. Pour a little bismuth trichloride ($BiCl_3$) solution into a beaker of water. Add concentrated HCl.

292. Add NH_4OH to a solution of bismuth. What is the composition of the precipitate? Is it an acid or a base? Compare with the phosphorus compound (?) having a similar formula.

293. Dilute a little $Bi(NO_3)_3$ or $BiCl_3$ solution with an equal volume of water and pass H_2S through the mixture until precipitation is complete. Filter; wash the precipitate on the filter by means of the wash bottle as shown

in Fig. 34. (The wash bottle can be easily constructed and should always be kept filled with water ready for use.)

Test the solubility of the precipitated bismuth sulphide (Bi_2S_3) in $(NH_4)_2S$ and in $(NH_4)_2S_x$. Does it dissolve? How does this test compare with similar tests on sulphides of arsenic and antimony?

294. To a solution of some bismuth compound add a little freshly prepared solution of sodium stannite. Why is this a good test for bismuth? What compound is formed?

(The sodium stannite solution is prepared by adding NaOH solution, a little at a time, to a solution of stannous chloride ($SnCl_2$), until the precipitate which is at first formed redissolves.)

Summary. Point out the ways in which bismuth, antimony and arsenic appear to be similar. Is bismuth ever acid in its chemical behavior? Is arsenic ever basic in its behavior? How does antimony stand with regard to these two? Make a table showing the oxides, chlorides and hydrides of each of the elements of this group.

Problems. (a) How much white arsenic can be produced from 500 lbs. of realgar? From 500 lbs. of orpiment?

(b) What volume of H_2S at standard conditions will be necessary to completely precipitate the arsenic from 200 gms. of a 15% solution of sodium arsenate, considering that only 20% of the H_2S is lost?

(c) From 25 gms. of white arsenic, what volume of arsine at 0° and 760 mm. can theoretically be produced?

(d) What weight of iron will be required to completely reduce 12 tons of pure stibnite?

(e) What volume of air at 20° and 765 mm. will be required in roasting 500 kilos of orpiment (containing 85% As_2S_3) to the oxide?

CHAPTER XIII.

THE ALKALIES AND AMMONIUM.

LITHIUM (Li; 7).

295. Thoroughly clean the end of a piece of platinum wire by dipping into concentrated HCl and then heating in the hottest part of the Bunsen flame. When clean, it will not color the flame. Then dip the clean wire into a solution of lithium chloride (LiCl) and again hold in the flame. What is the color of the lithium flame?

296. Look through the spectroscope towards the window and carefully focus the instrument so that a sharp image is produced. Then look through the spectroscope at the lithium flame. How many lines has the spectrum of lithium as seen through the small spectroscope? Draw a diagram of the spectrum showing the relative position of the lithium line.

SODIUM (Na; 23).

297. Place a small piece of metallic sodium on a watch glass and allow to stand exposed to the air for several days. Observe the various changes which take place. When crystals are at length formed, try the action of HCl upon them.

Write all equations and explain all changes which have taken place.

298. Drop a piece of metallic sodium about half the size of a pea into a beaker containing about 25 cc. of water. What gas is liberated? Why does the sodium

float on the water? Does it burn when it reacts with water? (Reserve the solution for use in Exp. 300.)

299. Dissolve about 10 gms. of crystallized sodium carbonate (Na_2CO_3) in 50 cc. of hot water. To a small portion of this solution add HCl. Does it effervesce? Why?

In a mortar mix about 10 gms. of $Ca(OH)_2$ with enough water to form a thin paste and add this mixture (milk of lime) to the solution of sodium carbonate. Filter and evaporate the filtrate to about one-third its volume. Filter again if not clear. Test a small portion of the solution with HCl. Does it effervesce? Why? What compound is in solution?

300. Compare the solutions obtained from Exps. 298 and 299. Test each solution with red and blue litmus paper. Do the solutions behave alike? Try the action of a portion of each solution on a solution of $FeCl_3$. Drop a little phenolphthalein into a portion of each solution.

301. Mix about 50 gms. of Na_2SO_4, 25 gms. $Ca(OH)_2$ and 200 cc. of water. Heat to boiling. Filter rapidly through a plaited filter. What compound is in solution in the filtrate? What is the residue?

Divide the clear filtrate into two equal portions. Saturate one portion with CO_2, filter if necessary, and then add the other portion. Filter again if the solution is not clear. Evaporate to about half the volume and allow to stand quietly to crystallize. What is the composition of the crystals? What is the object of proceeding in the above manner?

Dry the crystals between filter papers. Test a small portion with HCl. What does this prove?

302. Solvay Soda Process. Arrange an apparatus as shown in Fig. 35. Generate NH_3 in the flask on the ring stand by boiling a strong solution of NH_4OH. Pass the NH_3 through 25 cc. of a saturated solution of

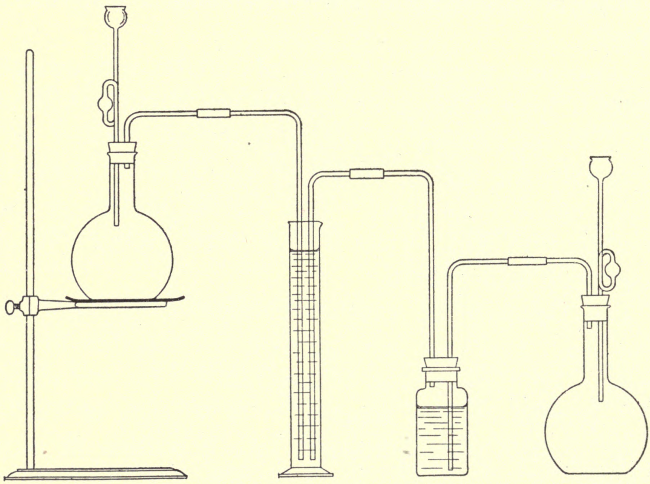


FIG. 35.

NaCl until it is saturated with the gas. Now remove the NH_3 generator and pass CO_2 from the other generator through the solution until saturated and a white precipitate is formed. What is the nature of this precipitate? Is it soluble in water? Test a small portion with HCl. How can this compound be changed into Na_2CO_3?

303. Le Blanc Soda Process. Make an intimate mixture of six parts of dry Na_2SO_4, four parts of powdered $CaCO_3$ and one part powdered charcoal. Grind them together in a mortar. Fuse a portion of the mixture on a piece of platinum foil.

Allow to cool, extract with a little hot water, and filter the solution. What does the filtrate contain? Test a portion of it with HCl. To another portion add a few drops of baryta or lime water.

304. **Insoluble Sodium Salt.** To a few cubic centimeters of a solution of potassium pyroantimonate ($K_2H_2Sb_2O_7$) add a few cubic centimeters of a strong solution of NaCl. Allow the tube containing the mixture to stand for some time. What is the composition of the crystals which are formed and which cling to the test tube? How many insoluble salts has sodium?

305. Heat a few good-sized crystals of NaCl (rock salt) in a test tube. Explain the phenomena observed.

In a porcelain mortar powder a large crystal of NaCl. Place the fine powder on a piece of platinum foil and heat strongly. What happens? Are there any little explosions?

306. Dip a clean platinum wire into a solution of NaCl and hold in the flame. What color is imparted to the flame by sodium and its compounds?

Repeat the experiment and examine the sodium flame as it appears through a piece of blue glass.

307. Examine the sodium flame through the spectroscope and make a diagram of the spectrum showing the sodium line. Mix a little sodium solution and lithium solution and make a spectroscopic test of the mixture. Can you recognize the lines of both elements?

POTASSIUM (K; 39).

308. Drop a small piece of potassium into a large beaker of water. (CAUTION! *To protect the eyes cover the beaker with a piece of paper or cardboard.*) How does this reaction compare with that between water and sodium?

Add a drop of phenolphthalein to the solution. What kind of a compound is in solution?

309. Dip a clean platinum wire into a solution of KCl and hold in the Bunsen flame. What color do potassium compounds impart to the flame?

Make a mixture of NaCl and KCl solutions and make a flame test of the mixture. Can you recognize the potassium flame? Repeat the experiment, looking at the flame through a piece of blue glass. Look at a plain potassium flame through a piece of blue glass. What flame do you conclude can be seen through the blue glass?

310. Look at the potassium flame through the spectroscope and draw a diagram of the spectrum. Make a mixture of solutions of NaCl, LiCl and KCl and examine the spectrum of the mixture. Can you recognize the lines of each element?

311. Add about 25 gms. of wood ashes to about 50 cc. of water in a beaker. Heat gently for 10 minutes. Filter the solution and evaporate the clear filtrate to dryness in a porcelain evaporating dish.

Test the residue with HCl. What happens and what does it signify? Dip a clean platinum wire into the solution in HCl and hold in the Bunsen flame. Also examine the flame with the spectroscope. What com-

pound was extracted from the wood ashes? What is one of the chief compounds in the ashes of sea plants?

312. Into a test tube containing a few drops of bromine, drop a very minute piece of metallic potassium. (CAUTION! HOOD.) Repeat, using sodium instead of potassium. What do you conclude as to the relative affinities of sodium and potassium for bromine?

313. In separate test tubes try the action of a solution of KOH on solutions of $FeCl_3$, $Pb(C_2H_3O_2)_2$ and $Cr_2(SO_4)_3$. Repeat, using NaOH instead of KOH. Do these two bases act alike?

314. **Insoluble Salts.** To a little concentrated KCl solution in a test tube add a few drops of platinum chloride solution. Allow to stand a few moments. Examine the precipitate. Divide the mixture into two parts and test one with hot water. Test the other portion with alcohol. What can you conclude as to the solubility of potassium platinum chloride (K_2PtCl_6)?

315. Mix about equal volumes of strong KCl solution and tartaric acid solution. Allow the mixture to stand undisturbed for 10 minutes. What is the composition of the precipitate which is formed? Why did it not form immediately?

Filter and wash the precipitate. Fuse a part or all of it on platinum foil. Cool and then test with a drop of HCl. What happens? What compound has been formed? Can you write the equation?

316. **Preparation of KNO_3.** Dissolve 25 gms. of crude KCl in about 50 cc. of water in a beaker. Add the calculated weight of $NaNO_3$. Filter the solution if necessary and evaporate the filtrate to half its volume.

Allow to stand and cool quietly. Filter; then dry the crystals between pieces of filter paper. Dissolve the crystals in about 15 cc. of boiling water and allow to cool and crystallize. Dry the crystals.

Examine the crystals by flame test and by means of the spectroscope. Dissolve a trace in a little water and test for nitric acid as directed in Exp. 154, page 71. What is the most probable impurity in these crystals? Did this impurity appear in the spectroscopic test? Can you explain why two soluble salts such as NaCl and KNO_3 can be separated by crystallization?

317. Oxidation by Means of KNO_3. Under the hood, heat a mixture of about 2 gms. KNO_3 and 1 gm. powdered charcoal in an iron crucible. Allow to cool, extract with water and filter. Test a portion of the solution with an acid. What is proved by this test?

318. Strongly heat about 2 gms. KNO_3 and 1 gm. of sulphur in an iron crucible. (Hood.) Allow to cool, extract with water and test a portion for the presence of sulphates. Explain the action and write equations.

Explain by equations how KNO_3 oxidizes. How many available oxygen atoms has KNO_3?

319. Potassium Iodide (KI). Dissolve 25 gms. of KOH in 150 cc. of distilled water by the aid of heat. Add iodine in very small quantities at a time and with constant stirring, until a further addition causes the liquid to remain brown. Concentrate the solution by boiling, add about 50 gms. of powdered charcoal and transfer to an evaporating dish or large crucible. Evaporate to dryness, cover and ignite for 20 minutes at a dull red heat. Dissolve the mass in warm water, filter, con-

centrate and set aside to crystallize. Purify by recrystallization from distilled water.

320. **Potassium Chlorate** ($KClO_3$). Slake 75 gms. of lime, mix with 30 gms. of KCl and add sufficient water to form a thin paste. Heat almost to boiling and pass in chlorine until no more is absorbed and the lime has passed into solution. Boil for an hour, passing CO_2 through it during the last 10 minutes, and filter while hot.

Evaporate the filtrate to 100 cc. and set aside to crystallize. Obtain a second and third crop of crystals from the mother liquor. Purify by recrystallization. The crystals should give no test for chlorides.

AMMONIUM (NH_4).

321. To a little sodium amalgam in a test tube add a strong solution of NH_4Cl. Notice the odor of the resulting compound. Can the group NH_4 be liberated? Why has this group been given a name ending in "um"?

322. Heat a small amount of NH_4Cl on a piece of platinum foil. What happens? Try $(NH_4)_2SO_4$ in the same way. Do sodium and potassium salts behave in a similar manner when heated? (See Exp. 305.)

323. Try the action of NaOH on a solution of some ammonium salt. Note the odor of the escaping gas. Test with turmeric paper. Warm the mixture if necessary.

324. Make a flame test with NH_4Cl. What color is imparted to the flame by ammonium salts?

325. Try the action of ammonium hydroxide (NH_4OH) on solutions of $FeCl_3$, $Pb(C_2H_3O_2)_2$, and

$Cr_2(SO_4)_3$. Compare results with those obtained from Exp. 313.

326. Test for an Ammonium Compound. Place a few grams of $Ca(OH)_2$ in a small beaker and moisten with the solution to be tested for ammonium salts. Quickly cover the beaker with a watch glass, on the under side of which is a piece of wet turmeric paper. Allow to stand for several minutes.

Try this test on a number of ammonium compounds.

327. Dissociation of NH_4Cl. Place a loose plug of asbestos fiber in the middle of a piece of large glass tubing. On one side of the plug and close to it, place a few grams of NH_4Cl. At each end of the tube introduce two pieces of moist litmus paper, one red and one blue.

Now gently heat the tube directly under the NH_4Cl to volatilize some of the latter. Carefully observe any changes in the litmus paper. What conclusion can you draw from the results of this experiment? Who was the first scientist to notice this phenomenon?

Summary. In what respects does ammonium hydroxide differ from the other alkali hydroxides? In what respects is ammonium hydroxide similar to the other alkali hydroxides? Why is ammonium grouped with the alkalies?

How can solutions of (1) lithium, (2) sodium, (3) potassium and (4) ammonium be distinguished? How can each of these be distinguished in presence of the others?

What is the relation between "ammonia" and "ammonium compounds"? Why does NH_4OH always have the odor of NH_3?

Problems. (a) To prepare 10 tons of crystallized sodium carbonate, how much sodium chloride is necessary?

(b) From 30 kilos of wood ashes containing 6% of K_2CO_3, what weight of 20% KOH solution can be made?

(c) From 10 lbs. of crude ammonium sulphate (94%), what volume of dry NH_3 gas can be prepared at 15° and 732 mm. pressure?

(d) Considering that NH_4Cl does not dissociate when vaporized, what volume will 260 gms. of NH_4Cl occupy when completely volatilized at 600° and 760 mm. pressure?

CHAPTER XIV.

THE ALKALINE EARTHS.

CALCIUM (Ca; 40).

328. Place a lump of lime (CaO) on a watch glass and add water, a few drops at a time, until the lime slakes. The water can be very conveniently added by means of a wash bottle (Fig. 34). Be careful to avoid an excess of water. Is heat liberated when the lime slakes? Why?

329. Place the slaked lime prepared above in a 500-cc. flask and add about 350 cc. of distilled water. Cork tightly and allow to stand with occasional shaking for an hour. Filter the solution into a clean flask and stopper tightly. Label the solution "Lime Water," and reserve it for use in experiments to follow.

Test the action of lime water towards litmus and turmeric paper. Test a few cubic centimeters with a drop of phenolphthalein solution.

330. Place a small piece of marble in a porcelain crucible, cover and ignite over the blast lamp for 15 minutes. Allow to cool, still covered. When cool, remove the cover and test the contents of the crucible for $Ca(OH)_2$ by means of wet turmeric paper and wet red litmus paper.

Write equations to show what happens when calcium oxalate (CaC_2O_4) is ignited, (1st) gently, and (2nd) with the full force of the blast lamp.

331. Treat about 200 cc. of spent liquid from a CO_2 generator with enough slaked lime to completely neutral-

ize the acid reaction. Filter the solution if not perfectly clear. To the filtrate add a clear solution of Na_2CO_3 until precipitation is complete. Allow the precipitate to settle, decant the supernatant liquid and add distilled water to the white precipitate. Filter, wash the precipitate on the filter, and allow to dry. When dry transfer to the stock bottle labelled "Precipitated Calcium Carbonate."

Test a small portion of the precipitate with HCl. What does this test show?

332. Treat a few cubic centimeters of lime water with CO_2 until the precipitate at first formed redissolves. Explain the phenomenon fully.

Divide the solution into two equal portions. Heat one portion to boiling for a moment. To the other portion add clear lime water. What is precipitated in each of these tests? What commercial use is made of these reactions?

333. Test separate portions of any calcium solution with solutions of ammonium oxalate ($(NH_4)_2C_2O_4$) and sodium phosphate (Na_2HPO_4).

334. Make a flame test for calcium, using a solution of $CaCl_2$ or any other calcium solution acidified with HCl.

Observe the spectrum of calcium and draw a diagram showing the various lines.

335. To 50 cc. of a clear solution of $CaCl_2$ add dilute H_2SO_4 until precipitation is complete. Filter and wash well with distilled water. Allow to drain. Then make a hole in the filter paper and by means of the wash bottle (Fig. 34) wash all of the precipitate into a clean flask. Add 150 cc. of water, cork tightly and allow to stand

with occasional shaking. Label the solution "$CaSO_4$, Saturated Solution," and reserve for future use.

336. To a few cubic centimeters of $CaCl_2$ solution add NH_4OH and $(NH_4)_2CO_3$ solution in slight excess. Filter. To the clear filtrate add a few drops of ammonium oxalate ($(NH_4)_2C_2O_4$) solution. Does a precipitate form? What does this experiment show as to the relative solubility of the carbonate and oxalate of calcium?

337. Heat a little calcium oxalate (CaC_2O_4) with concentrated H_2SO_4 in a test tube and test the gas evolved for (1) CO and (2) CO_2. Are both present? What is left in the tube?

338. **Plaster of Paris.** Powder a few grams of gypsum and heat in a porcelain dish, stirring the powder with a thermometer, and using great care to prevent the temperature rising above 120°. Why? Allow the mass to cool thoroughly.

Mix the cold powder with enough water to form a thick paste. Lay a coin on a glass plate and pour the paste over it. Allow to stand and harden. When perfectly hard, remove the coin and examine the impression.

339. Heat a second and smaller portion of gypsum in an iron crucible, using the full force of the Bunsen flame. Allow to cool; then mix with water and allow to stand. Does the mass set? In what does this latter preparation differ from plaster of Paris?

Phosphate Fertilizers.

340. **Insoluble Calcium Phosphate** ($Ca_3(PO_4)_2$). Treat a little powdered apatite or bone ash with a few cubic centimeters of distilled water and heat to boiling.

Filter and refilter until the solution is perfectly clear. Test the clear filtrate for phosphates by means of HNO_3 and ammonium molybdate solution (see Exp. 261). Is the apatite soluble in water?

To prove that the mineral contains phosphoric acid, dissolve a small portion in concentrated HNO_3 and again test with ammonium molybdate solution.

341. Preparation of Superphosphate ($Ca(H_2PO_4)_2$). Treat 20 gms. of powdered apatite or bone ash with 5 cc. of concentrated H_2SO_4 in a porcelain dish. Warm gently for about 10 minutes.

Add a small portion of the resulting mass to 15 or 20 cc. of water and test the solution thus formed for phosphates. (Save the remainder of the mass for use in Exp. 342.)

Has the action of the H_2SO_4 caused the insoluble phosphate to become soluble? Show by an equation how this was done?

342. Reverted Phosphate ($CaHPO_4$). To the mass, containing superphosphate which was left from Exp. 341, add 25 cc. of water and about 30 gms. of $Ca(OH)_2$. Heat to boiling, allow to stand 15 minutes, and then filter. (Save both the filtrate and the residue on the filter.)

Test a portion of the filtrate for phosphates. Do you get a test? Why? What has become of the superphosphate? (Equation.) Where is the reverted phosphate? Is reverted phosphate soluble in water?

Transfer the filter containing the residue to a small flask and treat with 20 cc. of a solution of ammonium citrate. Shake to thoroughly mix the contents. Warm gently for a few moments. After standing for 15 minutes, filter and test the clear filtrate with HNO_3 and

ammonium molybdate solution. What is present? Can you explain everything in this experiment? Of what use is reverted phosphate in a fertilizer?

Examination of Fertilizers.

(Qualitative.)

343. **Superphosphate.** Treat about 10 gms. of the fertilizer with 30 cc. of water in a small flask. Allow to stand, with occasional shaking, for 20 minutes. Filter and test the clear filtrate for phosphates. (Use the residue in the test for "reverted phosphate.")

Reverted Phosphate. Wash the residue in the filter (from the preceding test) several times with water to remove the last traces of superphosphate. Then transfer the filter paper and residue to a small flask, treat with 20 cc. of ammonium citrate solution, shake, and gently warm for about 20 minutes. Filter and test the clear filtrate for phosphates (reverted phosphate). (Save the residue on the filter for the next test.)

Insoluble Phosphate. Wash the residue from the preceding test with warm water to remove the last traces of ammonium citrate solution and reverted phosphate. Dissolve a portion of the clean residue in a little concentrated HNO_3 and test for phosphates (insoluble phosphate).

Potash. Treat a bit of the fertilizer on a watch glass with a drop or two of concentrated HCl. By means of a clean platinum wire, make a flame test of the resulting solution and observe the flame through a piece of blue glass. Can you detect the potassium flame?

Repeat and observe the flame through the spectro-

scope. Can you recognize the potassium lines? What other lines are visible?

In a small beaker treat about 1 gram of the fertilizer with 25 cc. of water and 3 gms. of $Ca(OH)_2$. After standing 5 minutes, filter. To the filtrate add NH_4OH in excess and a solution of $(NH_4)_2C_2O_4$ until precipitation is complete. Heat to boiling and filter while hot.

Evaporate the clear filtrate to dryness in a porcelain evaporating dish and heat gently until white fumes (ammonium salts) no longer come off. Cool; dissolve the residue in a few drops of water, filter if necessary through a very small wet filter, and to the clear filtrate add a few drops of platinum chloride solution (H_2PtCl_6). (See Exp. 314.) A yellowish red precipitate is K_2PtCl_6 and shows presence of potash.

Ammoniacal Nitrogen. This means nitrogen which is present in the form of ammonium salts. Test as described in Exp. 326, page 126.

Nitrogen as Nitrate. The above test does not show nitrogen present as nitrate. All nitrates are soluble in water. Treat a small portion of the fertilizer with distilled water, filter and test the filtrate for nitrates as directed in Exp. 154, page 71.

STRONTIUM (Sr; 87).

344. In separate test tubes try the action of solutions of the following substances on a solution of strontium: ammonium carbonate, sodium phosphate, potassium chromate and dilute H_2SO_4.

345. Make a flame test for strontium. What other elements give similar flame tests?

Observe the spectrum of strontium and draw a diagram

showing the more important lines. Compare the diagram with those of elements which give a flame test similar to strontium.

346. To about 15 cc. of a strontium solution add dilute H_2SO_4 until precipitation appears to be complete. Filter and wash the precipitate. Make a hole in the paper and by means of the wash bottle, wash the precipitate into a clean flask. Treat with about 50 cc. of distilled water. Cork tightly and allow to stand with occasional shaking. Label "$SrSO_4$, Saturated Solution," and reserve for future use. (Exp. 349.)

BARIUM (Ba; 137).

347. In separate test tubes try the action of solutions of the following substances on a solution of some barium salt: ammonium oxalate, sodium phosphate, sodium sulphate, ammonium carbonate, potassium chromate, and dilute H_2SO_4. Compare the results with those obtained from Exps. 333 and 344.

348. Make a flame test for barium, using $BaCl_2$ solution and a few drops of HCl.

Observe the spectrum of barium and draw a diagram showing the lines.

349. Relative Solubility of the Alkaline Earth Sulphates. Filter a little of the $SrSO_4$ solution prepared in Exp. 346. To a few cubic centimeters of this clear solution add an equal volume of some other strontium solution. Is there a precipitate formed? Why?

Filter a little of the $CaSO_4$ solution from Exp. 335 and test a few cubic centimeters of this with an equal volume of some strontium solution (other than $SrSO_4$). Is there a precipitate formed? Why is a precipitate produced

by a saturated solution of $CaSO_4$ and not by a saturated solution of $SrSO_4$? What do you conclude as to the relative solubility of the sulphates of calcium and strontium?

Add a few cubic centimeters of the saturated $CaSO_4$ solution to a solution of some barium salt. Does it produce a precipitate? Try the action of a little of the saturated $SrSO_4$ solution on a barium solution. Does this also cause a precipitate? What can you conclude as to the solubility of $BaSO_4$? Which of the alkaline earth sulphates is the least soluble and which is the most soluble? Are any of them as soluble as the alkali sulphates?

Determination of the Number of Molecules of Water of Crystallization in Barium Chloride.

(Quantitative.)

350. The determination of the number of molecules of water of crystallization in barium chloride is carried out in exactly the same manner as was the determination of the number of molecules of water of crystallization in gypsum. (See Exp. 44, page 31.)

Summary. In what general principles do the alkaline earths differ from the alkalies? What can you say as to the relative solubility of the compounds of these two groups of metals?

In what respects does lithium somewhat resemble the alkaline earths? In what respects does it more closely resemble the alkalies? What one point is alone sufficient to cause lithium to be placed in the group with the alkalies?

By what test or tests can each of the alkaline earths

be distinguished? Mention tests by means of which each of the alkaline earths can be detected in presence of the other two.

Problems. (a) How many kilos of lime can be prepared from 4 tons of pure $CaCO_3$?

(b) What volume of 15% HCl would be required to dissolve 1840 gms. of pure $CaCO_3$?

(c) How much gypsum is necessary for the preparation of 500 lbs. of plaster of Paris?

(d) By heating 15 liters of a 15% solution of calcium bicarbonate, what volume of CO_2 (standard conditions) will be liberated?

(e) How much lime will be necessary to completely soften 15 cubic meters of water in which the hardness is due entirely to calcium bicarbonate and in which this compound is present to the extent of 1.8%?

CHAPTER XV.

MAGNESIUM, ZINC, CADMIUM AND MERCURY.

MAGNESIUM (Mg; 24).

351. Burn a small piece of magnesium ribbon and allow the oxide to fall upon a watch glass. Add a drop of water, allow to stand for a moment and test the reaction towards litmus paper. What do you conclude from this test?

352. Test the solubility of magnesium in the dilute acids. Can you identify the gaseous products formed? Write all equations.

353. Test separate portions of a solution of $MgCl_2$ or $MgSO_4$ with solutions of the following substances: NH_4OH, $NaOH$, and Na_2CO_3.

354. Add a few cubic centimeters of NaOH solution to a solution of magnesium ($MgCl_2$ or $MgSO_4$). Is there a precipitate formed? Now treat the mixture with a strong solution of NH_4Cl. What happens? Why?

355. Evaporate 25 cc. of $MgCl_2$ solution nearly to dryness in a porcelain evaporating dish. Test the vapors occasionally by means of litmus paper. Do they have any reaction? Test the residue in the evaporating dish with litmus paper.

356. Mix 25 cc. of $MgCl_2$ solution with an equal volume of NH_4Cl solution in an evaporating dish and evaporate nearly to dryness, as in the preceding experiment. Likewise test the vapor and the residue with

litmus paper. Why do the results obtained differ from those obtained from the preceding experiment? Of what commercial importance are these experiments?

357. Dissolve 5 gms. of MgO in dilute H_2SO_4, avoiding an excess of acid. Filter the solution if not perfectly clear, and evaporate to a small volume. Allow to stand quietly and cool. Drain the crystals on a filter, redissolve them in a little hot water, and allow to recrystallize.

Examine the crystals. Note their taste. How many molecules of water of crystallization has $MgSO_4$? To what class of compounds does it belong?

358. Make a mixture of equal parts of solutions of NH_4Cl, NH_4OH and some magnesium salt ($MgCl_2$ or $MgSO_4$). What name is applied to this mixture? Why is the mixture a good reagent for phosphates? Try the action of the mixture on any phosphate solutions you find on the reagent shelves. Is a white precipitate formed in each case?

Try the action of an acid on a portion of the white precipitate of ammonium magnesium phosphate thus formed. To the solution in acid now add an excess of NH_4OH.

What gas would be liberated if you heated the ammonium magnesium phosphate? What residue would be left? Write the equation for this reaction.

359. Dissolve a piece of magnesium ribbon in dilute HNO_3 and evaporate the solution to dryness in a porcelain dish. (Hood.) Strongly ignite the dish and contents for a few moments. When cool, treat with a few drops of water and test with a piece of red litmus paper. Compare with Exp. 351.

ZINC (Zn; 65).

360. Test the solubility of metallic zinc in dilute and concentrated HCl, in dilute and concentrated H_2SO_4 and in HNO_3. Does it make any difference whether the acid is dilute or concentrated? What gaseous products are formed in each case?

361. Heat a small piece of zinc on charcoal with the oxidizing flame of the blowpipe. Notice the deposit of zinc oxide (ZnO) formed on the charcoal. Note its color when hot and when cold. Is there a difference?

Moisten the ZnO on the charcoal with a drop of a solution of cobalt nitrate ($Co(NO_3)_2$) and again heat with the blowpipe. What color is produced? What is the composition of the colored compound?

362. To a solution of $ZnSO_4$ gradually add NaOH solution until in excess. Note all the changes and write all equations. Name the two zinc compounds which have been formed in this experiment.

363. To a portion of the solution formed in Exp. 362 add dilute HCl a little at a time until the solution is acid to litmus. Explain all changes and give names of compounds formed.

364. Treat separate portions of $ZnSO_4$ solution with solutions of the following substances: Na_2CO_3, $K_4Fe(CN)_6$, and Na_2HPO_4.

365. Add a few drops of HCl to a test tube half full of $ZnSO_4$ solution and pass H_2S through the mixture. Is there a precipitate formed?

To a second portion of $ZnSO_4$ solution add $(NH_4)_2S$ solution. Divide the mixture into two portions and to one add concentrated HCl and to the other acetic acid

($HC_2H_3O_2$). What can you say as to the solubility of ZnS?

366. Heat a few crystals of $ZnSO_4$ in a dry test tube. Does $ZnSO_4$ contain water of crystallization? How many molecules? To what class of compounds does it belong?

CADMIUM (Cd; 112).

367. Heat a small piece of cadmium on a piece of charcoal with the oxidizing flame of the blowpipe. What color is cadmium oxide (CdO)?

368. Try the action of solutions of the following substances on separate portions of a solution of cadmium sulphate ($CdSO_4$): Na_2CO_3, $K_4Fe(CN)_6$ and Na_2HPO_4. Compare with the results obtained from Exp. 364.

369. To a little $CdSO_4$ solution add NaOH solution a little at a time until in excess. Does the cadmium solution behave like a zinc solution when treated in this way? (See Exp. 362.)

370. Pass H_2S through a solution of $CdSO_4$. Try the solubility of separate portions of the precipitate in (1) dilute HCl, (2) concentrated HCl and (3) $HC_2H_3O_2$. Compare with Exp. 365.

How does the solubility of CdS compare with the solubility of ZnS?

MERCURY (Hg; 200).

371. In a hard glass test tube heat a little of any mercury compound with about twice as much dry Na_2CO_3. What is the composition of the sublimate? Rub it with a glass rod.

372. Place a little cinnabar (HgS) in the middle of a piece of hard glass tubing open at both ends, and clamp

the tube in a slightly inclined position. Strongly heat the tube at the point just below the HgS.

Notice the sublimate formed. Also notice the odor of any gases coming from the upper end of the tube. Test their action on wet blue litmus paper.

373. Using minute globules of mercury, test the solubility of the latter in both dilute and concentrated HCl, dilute and concentrated H_2SO_4, and dilute and concentrated HNO_3. Likewise test the solubility of the metal in aqua regia. If reaction does not take place in the cold with any of the above-mentioned acids, apply heat. Notice the gaseous products formed in each case. (*Empty all mercury residues into the bottle labeled "Mercury Residues."*)

374. Prepare sodium amalgam by adding two or three small, dry, freshly cut pieces of sodium to a little dry mercury in a porcelain mortar. (CAUTION.) Examine the product. Does it look any different from mercury?

Divide the amalgam into two portions in test tubes. To one portion add water and test the gas evolved with a burning splinter. To the other portion add strong NH_4Cl solution. Have you ever performed this latter test before? What becomes of the mercury in these tests?

Mercurous Compounds.

375. Prepare a solution of mercurous nitrate by treating about half a cubic centimeter of mercury with a little moderately strong HNO_3 (1 : 1) in a test tube. Allow the tube to stand for some minutes. There should be some mercury left in the bottom of the tube. Dilute the solution with 10 cc. of water containing a drop of concentrated HNO_3 and use in the tests to follow.

376. Try the action of NaOH and NH_4OH on separate portions of $HgNO_3$ solution. Through another portion pass H_2S until precipitation is complete.

377. To separate portions of $HgNO_3$ solution add dilute HCl and a solution of NaCl. Do these two reagents precipitate the same compound?

To one of the tubes add an excess of NH_4OH. Save the other tube for another experiment.

Mercuric Compounds.

378. Prepare a solution of mercuric chloride ($HgCl_2$) by dissolving a globule of mercury in aqua regia. Evaporate to small volume and then dilute with 15 cc. of water. Use the solution in the tests to follow.

379. In separate test tubes try the action of NaOH solution and NH_4OH on portions of the solution of $HgCl_2$ from the preceding experiment. (Compare with Exp. 376.) Through another portion pass H_2S for a time and watch the various changes. Test the solubility of this precipitate in strong HCl and HNO_3.

380. To a few cubic centimeters of $HgCl_2$ solution add a solution of KI, a little at a time, until precipitation is complete. Avoid an excess. Divide into two portions.

To one portion add more KI solution until the precipitate just redissolves. Now add an equal volume of strong KOH solution. What is the name of the mixture thus formed? What use is made of this mixture? (See Exp. 33, page 27.) Try its action on a solution of NH_4Cl.

381. Decant the supernatant liquid from the other half of the precipitate of HgI_2 formed in Exp. 380, and then dissolve in a few drops of concentrated HCl by the aid of heat. Allow to cool. What crystallizes out?

382. Treat the white precipitate of HgCl saved from Exp. 377 with a little aqua regia and boil for a moment. Does the precipitate dissolve? Why? Has there been a change in the composition of the mercury compound? Dilute the solution and apply tests to ascertain whether the solution now contains a mercurous or a mercuric compound.

383. Immerse a piece of clean bright copper foil in a little dilute $HgCl_2$ solution and allow to stand quietly for a time. Explain the phenomenon observed.

384. To a little $HgCl_2$ solution add a solution of stannous chloride ($SnCl_2$). What happens? Add NH_4OH to the mixture. Does this prove the presence of a mercurous or a mercuric compound? How has the $SnCl_2$ affected the mercuric salt?

Summary. Mention three tests by which zinc and cadmium can be distinguished. In what respects does mercury differ from both zinc and cadmium? Compare the solubility of the sulphides of mercury, zinc and cadmium. Compare the solubility of mercurous and mercuric compounds.

Problems. (a) From 5 tons of zinc ore assaying 87% ZnS, how many kilos of 99% zinc can be theoretically extracted?

(b) What will be the volume occupied by 100 cc. of mercury if volatilized at 1000° and 740 mm. pressure?

(c) From 150 liters of a solution containing 10% of mercuric chloride, how many cubic centimeters of mercury can be obtained?

CHAPTER XVI.

COPPER, SILVER AND GOLD.

COPPER (Cu; 63).

385. In separate test tubes try the action of dilute HCl, HNO_3 and H_2SO_4 on small pieces of copper. If reaction does not take place in the cold, try the effect of heat. Repeat these tests using concentrated acids instead of dilute.

Note the products formed in each case and write all equations.

386. Into a solution of $CuSO_4$ introduce a bright piece of sheet iron or an iron nail. Allow to stand for a moment; then examine the iron. What change has taken place?

Repeat the experiment, using a bright piece of aluminum or zinc. Do these metals act the same as iron?

387. Heat a piece of bright copper for a moment in the upper (oxidizing) part of the Bunsen flame. Does the copper change in appearance? Heat the piece of copper a second time and, while still hot, drop it into a test tube containing a few drops of alcohol. Explain all changes.

What would happen if black copper oxide were heated in a stream of hydrogen?

388. In separate test tubes try the action of solutions of each of the following compounds on $CuSO_4$ solution: $K_4Fe(CN)_6$, Na_2CO_3 and Na_2HPO_4.

389. Treat a small amount of $CuSO_4$ solution with NH_4OH, a drop at a time, until in excess. To a liter of water add two or three drops of $CuSO_4$ solution and then an excess of NH_4OH. What do you conclude as to the delicacy of this test?

To a beaker of water add a drop or two of $CuSO_4$ solution and then a few cubic centimeters of $K_4Fe(CN)_6$ solution. (See Exp. 388.) Which is the more delicate test for copper, NH_4OH or $K_4Fe(CN)_6$?

390. Add NaOH to $CuSO_4$ solution in a test tube. Notice the color of the precipitate. Now heat the tube and contents until the liquid boils. What change has taken place?

391. Pass H_2S through a solution of $CuSO_4$. Filter and wash the precipitate. Test the solubility of small portions of the precipitate in HCl and in HNO_3.

392. Add KI solution to $CuSO_4$ solution. Filter and wash the precipitate. Test a portion of the filtrate by adding a few drops of CS_2. What does this test prove? What is present in solution in the filtrate?

Examine the precipitate on the filter. Is it soluble in water? Heat a little on a crucible cover. Explain the change which takes place.

393. Powder some crystals of copper sulphate in a porcelain mortar. What is the color of the powder? Put the powder in a porcelain evaporating dish and heat gently over the Bunsen flame. What change takes place? Why must care be used to avoid heating too strongly?

Allow the powder to cool; then treat with a few drops of water. Explain all color changes.

394. To a few cubic centimeters of $CuSO_4$ solution

add the same volume of a solution of sodium and potassium tartrate ($NaKC_4H_4O_6$). Then add NaOH. Is there a precipitate formed? (Compare with Exp. 390.) To the mixture add a few cubic centimeters of grape sugar solution and heat to boiling. What happens?

What is the name of the mixture of $CuSO_4$, NaOH and $NaKC_4H_4O_6$ solutions? For what is it a test? Try the action of the mixture on a solution of cane sugar.

395. Treat a few cubic centimeters of $CuSO_4$ solution with KCN solution, a drop at a time, until the color disappears. Now pass H_2S through a portion of the solution. (Compare with Exp. 391.)

396. Precipitate copper ferrocyanide ($Cu_2Fe(CN)_6$) by adding $CuSO_4$ to $K_4Fe(CN)_6$ solution. (See Exp. 388.) Treat the precipitate with strong NaOH or KOH. Explain the action of the latter on the precipitate.

397. Treat about 5 gms. of copper turnings with a little aqua regia in a small flask and boil vigorously for a moment. Add 5 cc. concentrated HCl and boil for 5 minutes. Allow to settle for a moment and then pour the clear supernatant liquid into a large beaker full of distilled water. Notice the color of the precipitate.

Filter rapidly and wash the precipitate with a little water. Test the solubility of small portions of the precipitate in HCl, in water and in NH_4OH. Heat a small portion on a crucible cover.

What is the composition of the white precipitate formed above? Have you prepared any other cuprous compounds in the preceding experiments on copper?

Determination of the Atomic Weight of Copper by Means of the Specific Heat.

(Law of Dulong and Petit.)

398. **Apparatus.** Calorimeter (consisting of two beakers, one inside the other, the intervening space being filled with cotton or wool), thermometer, beaker of boiling water, balance, burner and ring stand, piece of thread, metal to be determined.

Determination of Specific Heat. Carefully weigh the empty calorimeter. Fill about two-thirds full of distilled water and again weigh. The difference equals the weight of the water, W. Carefully weigh the given piece of copper and let this weight be represented by M. By means of a piece of thread, suspend the metal in boiling water for several minutes. The metal is thereby heated to 100°. Carefully note the temperature (T) of the water in the calorimeter. Take the metal from the boiling water, shake to free it from adhering water, and quickly introduce into the calorimeter. Stir the water in the latter constantly, at the same time watching the thermometer to note the maximum rise in temperature. Let the maximum temperature be represented by T'.

Data:

Weight of water........................	W
Weight of metal........................	M
Temperature of metal....................	100°
Initial temperature of water in calorimeter...	T
Maximum temperature of water in calorimeter	T'

Inasmuch as the heat lost by the metal is just equal to

the heat absorbed by the water, the specific heat is found by the following formula:

$$\text{Specific Heat} = \frac{W(T' - T)}{M\,(100^\circ - T')}.$$

Determination of Atomic Weight. According to the law of Dulong and Petit, the specific heat multiplied by the atomic weight is equal to the constant 6.4. Therefore:

$$\text{Atomic Weight} = \frac{6.4}{\text{Specific Heat}}.$$

Compare the atomic weight of copper, as determined above, with that given in the table of atomic weights in the Appendix. Note error and percentage error.

Obtain from the instructor an unknown metal and determine its atomic weight by the method described above. Compare the atomic weight thus determined with the atomic weight table and draw your conclusions as to the metal employed.

SILVER (Ag; 108).

399. Dissolve a silver coin in dilute HNO_3 and evaporate the solution to dryness, but do not heat the dry powder. Dissolve in distilled water and filter if not clear. Why is the solution green in color? Test a drop of the solution with a few drops of NH_4OH. What does this prove?

Divide the solution into two portions. Into one portion drop a few minute pieces of copper turnings and allow to stand quietly for some time. Then carefully

examine the deposit. Filter and wash the crystalline precipitate of silver. Pick out any particles of copper which remain. Dissolve the silver in dilute HNO_3, avoiding an excess, and use this solution of silver nitrate ($AgNO_3$) in the experiments to follow.

400. To the other portion of the solution from the above experiment add dilute HCl until precipitation is complete. Note the color of the precipitate. Heat to boiling, filter and wash with a little hot water containing a drop of HNO_3.

Examine the precipitate. Test the solubility of small portions of it in HCl, HNO_3 and in NH_4OH. To the solution in the latter reagent add concentrated HNO_3.

401. Add KCN solution to $AgNO_3$ solution, a little at a time, until the precipitate redissolves. What commercial use is made of such a solution of silver?

402. Try the action of solutions of the following reagents on small portions of $AgNO_3$ solution: Na_2CO_3, NH_4OH, K_2CrO_4, NaOH and Na_2HPO_4.

403. Pass H_2S through a little $AgNO_3$ solution and test the solubility of the precipitate in HNO_3.

Put a drop of $(NH_4)_2S$ solution on a bright silver coin. What is the chemistry of the action? How can the coin be cleaned? Try concentrated HCl on it.

404. To about one-fourth of a test tube full of $AgNO_3$ solution add NH_4OH a little at a time until the precipitate which is first formed redissolves and the solution is alkaline to litmus. Now add about half the volume of a clear solution of sodium and potassium tartrate ($NaKC_4H_4O_6$), commonly called "Rochelle Salt," and allow to stand quietly for a time.

405. To separate portions of $AgNO_3$ solution add

NaCl, KBr and KI solutions. Note the color of each precipitate at the moment it is formed.

Filter each separately and spread the filter paper in the sunlight. After a few moments examine the precipitate. Which has been most noticeably changed by the action of the light? What use is made of these silver salts?

Precipitate a little AgCl and test the solubility of the precipitate in a solution of sodium thiosulphate ($Na_2S_2O_3$). What use does a photographer make of $Na_2S_2O_3$?

406. Fuse a little of a mixture of AgCl (from Exp. 400) and dry Na_2CO_3 on a piece of charcoal, using the reducing flame of the blowpipe. Examine the product.

407. Test the solubility of the metallic globule thus formed in hot and cold concentrated HCl. Wash it thoroughly and test with hot and cold H_2SO_4. Does silver dissolve in either of these acids? Must the acid be heated?

GOLD (Au; 197).

408. In separate test tubes try the action of solutions of the following substances on small portions of gold chloride ($AuCl_3$) solution acidified with H_2SO_4: $FeSO_4$, $SnCl_2$ and oxalic acid ($H_2C_2O_4$). Allow to settle. Examine the precipitates.

Mix the precipitates in a flask, heat to boiling and filter. Wash the precipitate with a little hot water. Note the color of the precipitate.

409. Heat a small portion of the precipitate (from Exp. 408) on a porcelain crucible cover. What change takes place?

410. Try the solubility of small portions of the

powdered gold prepared in Exp. 408 in HCl, HNO_3, H_2SO_4 and in aqua regia. What can you say of the solubility of gold?

411. Combine all the gold left from the preceding experiments, treat with aqua regia and evaporate carefully to dryness. What is the residue? Now heat strongly—full force of the Bunsen flame. What change takes place?

Dissolve in aqua regia and again evaporate almost to dryness. Take up in about 15 cc. of water and use this solution in the tests to follow.

412. In separate test tubes try the action of the following reagents on a few drops of $AuCl_3$ solution: NaOH, H_2S and KI. Do any of these reactions resemble the corresponding reactions with copper?

(*Empty all gold residue and solutions into the bottle labeled: "Gold Waste."*)

Summary. Compare the valences of copper, silver and gold. Why are these metals placed in the same group? Why are they grouped with the alkalies?

Compare the action of NaOH and of NH_4OH on solutions of copper, silver and gold.

What is the relative stability of copper, silver and gold compounds?

Problems. (a) From 580 gms. of crystallized copper sulphate, dissolved in water and treated with an excess of KI solution, how many grams of cuprous iodide will be produced?

(b) What is the equivalent weight of copper? Of silver? Of gold? How much copper will be required to precipitate all the silver from 12 liters of a 16% solution of $AgNO_3$?

(c) A solution of gold chloride contains 2% of gold. What weight of crystallized ferrous sulphate will be necessary to completely precipitate all the gold from 8 liters of this solution?

CHAPTER XVII.

TIN AND LEAD.

TIN (Sn; 119).

413. In separate test tubes treat small pieces of tin foil with dilute and concentrated HCl, HNO_3 and H_2SO_4. If reaction does not proceed at the ordinary temperature, apply heat. Try the solubility of tin in aqua regia.

Stannous Compounds.

414. Prepare a solution of stannous chloride ($SnCl_2$) by treating several small pieces of tin foil with 15 cc. of concentrated HCl in a small flask. Warm gently to hasten the reaction. If all the tin dissolves, add a few more pieces — there should be some tin left to keep the solution in the stannous condition

Dilute with 15 cc. of water. Label the solution "Stannous Chloride," and use in the tests to follow.

415. To a solution of stannous chloride ($SnCl_2$) add NaOH solution, a little at a time, until precipitation is complete. What compound is formed? Now continue to add NaOH solution until the precipitate redissolves. What compound of tin is now in solution? Is it a stannous compound? For what element is the solution thus prepared a good reagent or test?

416. Acidify a solution of $KMnO_4$ with HCl; then add $SnCl_2$ solution. Repeat, using a solution of $K_2Cr_2O_7$ instead of $KMnO_4$.

Try the action of $SnCl_2$ solution on a solution of $HgCl_2$.

What is the chemical behavior of $SnCl_2$ in these tests?

417. Pass H_2S through a few cubic centimeters of $SnCl_2$ solution until precipitation is complete. Note the color of the precipitate. Filter and wash the precipitate. Test the solubility of small portions of the precipitate in HCl and HNO_3. Also test the solubility of small portions in warm solutions of ammonium sulphide ($(NH_4)_2S$) and in yellow ammonium sulphide ($(NH_4)_2S_x$). To the solution in the latter reagent add HCl; note the color of the precipitate.

(Save a portion of the precipitate produced by H_2S on $SnCl_2$ solution for comparison.)

Stannic Compounds.

418. To a few cubic centimeters of stannic chloride ($SnCl_4$) solution add NaOH, a little at a time, until in excess. What compound is now in solution?

419. Try the action of $SnCl_4$ solution on a solution of $HgCl_2$. Also try it on $K_2Cr_2O_7$ solution. Is $SnCl_4$ a reducing agent? Why?

420. Treat about a gram of tin foil with 2 or 3 cc. of concentrated HNO_3 in an evaporating dish under the hood. When reaction ceases, warm gently to drive off excess of HNO_3 and dry the powder. Mix the dried powder with about twice its bulk of KCN on a piece of charcoal. (CAUTION! *Do not handle KCN with the hands.*) Under the hood, fuse the mixture on the charcoal, using the reducing flame of the blowpipe. Heat for several minutes.

Cut away the charcoal where the mixture was heated, grind it in a mortar, and treat with water to wash away the particles of charcoal. What is left? Is it tin?

How can it be tested for tin? Try dissolving it in concentrated HCl and adding to a solution of $HgCl_2$. If a white precipitate is formed, what is indicated?

LEAD (Pb; 207).

421. In separate test tubes treat small pieces of metallic lead with concentrated and dilute HCl, HNO_3 and H_2SO_4. Also try the solubility of lead in $HC_2H_3O_2$ and in aqua regia.

422. Heat a little litharge (lead oxide, PbO) on charcoal with the reducing flame of the blowpipe. Examine the metallic globule of lead. Repeat, using a sample of paint base to ascertain if it is white lead.

423. Immerse a strip of zinc in a solution of lead acetate ($Pb(C_2H_3O_2)_2$) and allow to stand quietly. Can you explain the action? What is the relative position of these two elements in the electrochemical series of the elements?

424. To separate portions of a solution of $Pb(C_2H_3O_2)_2$ add solutions of K_2CrO_4, Na_2CO_3, NaCl or HCl, dilute H_2SO_4 and KI. (See Exp. 425.)

425. Heat the tubes containing the precipitates of $PbCl_2$ and PbI_2 from the previous experiment. What happens? Now let the tubes stand quietly and cool. Note the crystals formed.

426. Try the action of concentrated HCl on lead oxide (PbO) and on lead dioxide (PbO_2). Notice any gaseous products. Explain the difference in the two reactions.

427. To a portion of $Pb(C_2H_3O_2)_2$ solution add NaOH, a little at a time, until the precipitate which is at first

formed redissolves. What two compounds have been made in this test?

Divide the solution into two equal portions. To one portion add a little HCl to cause reprecipitation.

428. To the other part of the solution formed in the previous experiment add a freshly prepared solution of NaClO. What is the composition of the precipitate?

429. Treat a little red lead (lead tetroxide, Pb_3O_4) with dilute HNO_3. Examine the residue. Dilute the mixture with water and filter. Test the filtrate to ascertain if it contains lead.

430. Heat a little NaOH solution with a trace of PbO_2. What happens? What compound is formed? Is it the same as the compound formed in the first part of Exp. 427?

431. Pass H_2S through a solution of $Pb(C_2H_3O_2)_2$ until precipitation is complete. Test the solubility of the resulting sulphide in HNO_3 and in $(NH_4)_2S$ solution.

Summary. To what group of elements do tin and lead belong? What is the characteristic valence of the elements of this group? What other metallic element belongs to this group? Why do we not experiment with this element in the laboratory?

Make a table of all the oxides of tin and lead, arranging them according to the oxygen content.

Problems. (a) How many grams of HgCl can be precipitated by 120 cc. of a 15% $SnCl_2$ solution from an excess of $HgCl_2$ solution?

(b) How many cubic centimeters of 55% HNO_3 will be required to oxidize to $SnCl_4$ all the $SnCl_2$ in 370 cc. of a 12% solution?

(c) How many pounds of iron will be required to reduce 1600 lbs. of galena containing 94% PbS?

(d) By oxidizing 8 kilos of metallic lead to Pb_3O_4 and treating this product with HNO_3, how many kilos of lead dioxide can be produced?

CHAPTER XVIII.

ALUMINUM AND CHROMIUM.

ALUMINUM (Al; 27).

432. Test the solubility of metallic aluminum in the various mineral acids, both dilute and concentrated. Heat if necessary.

Likewise try the action of boiling KOH or NaOH on aluminum. Identify the gaseous products formed in each case.

433. Test the action of NH_4OH on a solution of aluminum. Add excess of NH_4OH and then heat to boiling. Allow to stand for a moment. Examine carefully.

434. To a solution of aluminum sulphate ($Al_2(SO_4)_3$) add NaOH, a little at a time, until in decided excess. Test the solution thus formed as follows:

Heat a portion to boiling; allow to stand for a moment. (Compare with Exp. 433.)

To a second portion add strong NH_4Cl solution and heat gently. Is a gas evolved? Test with moist turmeric paper and by the odor. What is the precipitate?

435. Try the action of Na_2CO_3 solution on a solution of an aluminum salt. Compare the precipitate with that obtained by means of NH_4OH and NaOH.

Filter and wash the precipitate. Test with HCl to ascertain if it is a carbonate.

Try the action of a solution of $(NH_4)_2S$ on a solution of aluminum. What is the composition of the precipi-

tate? How can this be explained? What action does H_2S have on aluminum solutions? How can aluminum sulphide be made?

436. Place a little aluminum oxide on a piece of charcoal, moisten with a drop of cobalt nitrate ($Co(NO_3)_2$) solution, and heat strongly before the blowpipe. Notice the color of the product. This is a good test for aluminum.

437. Treat a little aluminum solution with a solution of Na_2HPO_4. What is the composition of the white precipitate? Test its solubility in acids.

438. **Preparation of Alum from Clay.** Under a good hood treat 35 gms. of clay with 10 cc. of concentrated H_2SO_4 in an evaporating dish. Heat the mixture gently for about 20 minutes. Allow to cool. Then transfer the mixture to a beaker containing 50 cc. of water. Rinse out the dish with a little of the water and add the washings to the beaker.

Heat the mixture in the beaker almost to boiling and add about 3 gms. of iron filings. Keep warm for 10 minutes.

Dissolve 8 gms. of crude $(NH_4)_2SO_4$ in the mixture and filter while still hot. Evaporate the clear filtrate to one-half its volume and set aside to crystallize. When cold, filter and wash the crystals with a few cubic centimeters of cold water.

Taste the crystals. Dissolve one in water and test the solution for aluminum. Explain this experiment in full.

Determination of the Number of Molecules of Water of Crystallization in Alum.

(Quantitative.)

439. In the determination of the number of molecules of water of crystallization in alum, the temperature should not be allowed to go above 200°. The crucible must not be heated on a triangle with the open flame but should be imbedded in a sand bath. The temperature is thereby more easily controlled.

Aside from the manner of applying the heat, the determination is carried out exactly as the determination of the number of molecules of water of crystallization in gypsum (Exp. 44, page 31).

440. Aluminum as a Mordant. To 20 cc. of alum solution add a slight excess of NH_4OH, heat to boiling and filter. Dissolve the precipitate on the filter in dilute $HC_2H_3O_2$ and allow the solution to run into a clean beaker.

Place a few cubic centimeters of this solution in a test tube and boil for a moment. Allow to settle. Explain fully.

Place a piece of white cotton cloth in a beaker of dye (alizarin) and heat to boiling. Then wash the cloth, wring out the excess of water and allow to dry.

Saturate a second piece of white cotton cloth in the remainder of the aluminum acetate solution previously prepared. Squeeze out the excess of solution, introduce into the beaker of dye and heat to boiling for a moment. Then wash the cloth thoroughly, wring out and dry as before. Compare the two pieces of cloth. Why is there a difference in color?

441. Mordants. Saturate one piece of cloth with a solution of alum, a second with a solution of $FeCl_3$ and a third with a solution of alum containing a few cubic centimeters of $FeCl_3$ solution. The pieces of cloth should be marked in some way so that they can be distinguished.

In separate beakers now saturate the three pieces of cloth in dilute NH_4OH. Then wash each piece thoroughly, wring out as much of the liquid as possible, and heat them together for 10 minutes in a beaker of the dye. Rinse, wring out and compare the colors.

(If the results of this experiment are approved by the instructor, the three pieces of cloth may be trimmed and glued in the notebook.)

442. Cement. Mix a few grams of cement with enough water to form a thick paste. Place on a piece of glass and mold into a thin pat by means of a spatula or a knife blade. Allow to stand several days to harden.

What is the explanation of the hardening of cement? What are the two essential compounds in cement?

Examination of Cement.*

(Qualitative.)

443. Silica. Dissolve about a gram of cement in dilute HCl in an evaporating dish and evaporate to dryness. Moisten the residue with a few drops of dilute HCl, add 20 cc. of water and warm gently. Filter and wash the precipitate. Test the precipitate for silica by tests described in Exps. 235 and 236. (Use the filtrate in the next test.)

* The reagents used in these tests must be chemically pure.

Alumina and Iron. To the filtrate from the preceding test add NH_4OH until alkaline, heat to boiling and filter. What is the white gelatinous precipitate? Dissolve a bit in NaOH and add NH_4Cl solution. What does this prove?

Dissolve a portion in dilute HCl, add a drop of concentrated HNO_3 and heat to boiling. Cool under the faucet; then add a drop or two of KCNS solution. What does this prove? (Use the filtrate in the next test.)

Lime. To the filtrate from the preceding test add a few drops of NH_4OH. Heat to boiling and add an excess of a solution of $(NH_4)_2C_2O_4$. Boil for a moment; filter hot and wash with a little hot water containing a drop of NH_4OH.

Place the filter paper containing the precipitate in a clean porcelain crucible and heat gently until dry, and then strongly until the paper is burned. Now cover the crucible and ignite in the blast flame. Allow to cool. Then remove the cover and treat the residue with a few cubic centimeters of water. Filter through a small filter and test the solution with turmeric paper and with Na_2CO_3 solution.

(Save the filtrate from the precipitation with $(NH_4)_2$-C_2O_4 for use in the next test.)

Magnesia. Evaporate the filtrate from the above test to small volume (10 or 15 cc.). Then add an excess of NH_4OH and $(NH_4)_2HPO_4$ solution. Allow to stand several minutes. What is the composition of the precipitate? What compound would be formed if this precipitate were strongly ignited?

(Use the filtrate from this test in the test for alkalies.)

Alkalies. Evaporate the filtrate from the preceding test to dryness and heat gently to drive out all ammonium salts (white fumes). Cool; treat with two or three drops of dilute HCl and test for Na and K by means of the flame test or with the spectroscope.

Sulphuric Acid. To test for sulphuric acid dissolve a small amount of the cement in dilute HCl, filter, and to the clear filtrate add a few drops of $BaCl_2$ solution. If the white precipitate is insoluble in concentrated HNO_3, it is $BaSO_4$ — showing the presence of SO_3 in the cement.

CHROMIUM (Cr; 52).

444. **Chromic Compounds.** To a solution of a chromic compound as chromic sulphate ($Cr_2(SO_4)_3$), or chromic chloride ($CrCl_3$), add NaOH solution, a little at a time, until in excess. Explain all changes.

Divide the solution into two portions and heat one to boiling. Allow to stand for a moment; then compare with the other portion.

445. Repeat the previous experiment, using NH_4OH instead of NaOH. Note all changes and compare with Exp. 444.

446. To a solution of a chromic salt add a strong solution of Na_2CO_3. What gas is evolved? Why is it evolved? Compare with Exp. 435.

447. Mix 5 gms. of powdered potassium dichromate ($K_2Cr_2O_7$) with 1 gm. of flowers of sulphur and introduce the mixture into a porcelain crucible. Heat in the flame of the blast lamp for 10 minutes.

Cool, boil the residue with water, filter and dry the green powder left on the filter. Test its solubility in acids.

448. **Oxidation of Chromic Compounds to Chromates.** Add NaOH to a $CrCl_3$ solution until the precipitate which is first formed redissolves. Then add about an equal volume of bromine water and heat to boiling. Does the solution change in color? Acidify with $HC_2H_3O_2$. Test a portion with a solution of $BaCl_2$.

449. Make an intimate mixture of 1 gm. of finely powdered chrome iron ore ($FeCr_2O_4$), 4 gms. dry Na_2CO_3 and 2 gms. KNO_3. Fuse the mixture in an iron crucible over the blast lamp. Allow to cool, extract the melt with hot water and filter. Neutralize the solution with $HC_2H_3O_2$ and test a portion for chromates by adding $AgNO_3$ solution.

450. Fuse a pinch of the green residue from Exp. 447 on platinum foil with a little Na_2CO_3. Why is this a good test for chromium? Dissolve in a drop of water and test as in Exp. 449.

451. **Chromates.** To separate portions of a solution of K_2CrO_4 add solutions of $Pb(C_2H_3O_2)_2$, $BaCl_2$ and $AgNO_3$. Divide each precipitate into two portions and test the solubility in HNO_3 and in $HC_2H_3O_2$.

452. Add a few drops of concentrated H_2SO_4 to a solution of K_2CrO_4. What change in color do you notice? Repeat the experiment, using some other acid.

To a solution of potassium dichromate ($K_2Cr_2O_7$) add NaOH solution. What change takes place? Are these two reactions oxidation reactions? Are they reducing reactions?

453. **Chromic Acid.** To a few cubic centimeters of $K_2Cr_2O_7$ solution add about an equal volume of concentrated H_2SO_4. Allow to stand quietly until cool. What is the nature of the red crystals formed? Pour

off the supernatant liquid and test the solubility of the crystals in water.

454. **Reduction of Chromates.** To separate portions of a chromate solution acidified with HCl add solutions of H_2S and $SnCl_2$. Describe each change and write all equations.

To another portion of a chromate solution acidified with H_2SO_4 add a few cubic centimeters of alcohol. Heat to boiling; note odor and change in color. Explain fully and write an equation to represent the reaction.

455. To a test tube half full of water add a few drops of K_2CrO_4 solution and a little dilute H_2SO_4. Now add about a half-inch layer of ether and then a few cubic centimeters of hydrogen peroxide. Agitate slightly and allow to stand quietly for an instant. Examine the color of the solution and of the ether. After 10 minutes again examine the colors. Note and explain all changes. This is a good test for a chromate and for H_2O_2.

456. **Chrome Alum ($K_2Cr_2(SO_4)_4.24H_2O$).** Dissolve 100 gms. of $K_2Cr_2O_7$ in warm water. Add 85 cc. of concentrated H_2SO_4 carefully and allow to cool to about 30°. Add alcohol slowly until there is no further action, being careful to keep the temperature down while doing so. When a further addition of alcohol does not cause a reaction to take place, filter, concentrate and set aside to crystallize.

Summary. What is the usual color of chromic compounds? What is the color of most chromates? Of dichromates? What is the valence of chromium in each of these three series of compounds? Has chromium any other valence?

Mention several ways in which chromium (1) differs from and (2) resembles aluminum.

Problems. (a) How many cubic centimeters of H_2S gas at 75° F. and 788 mm. pressure will be required to completely reduce 1080 cc. of an acid solution containing 16% $K_2Cr_2O_7$ and having a specific gravity of 1.112?

(b) From 1 ton of chrome iron ore containing 92% actual chromite ($FeCr_2O_4$), what weight of chrome yellow can be made?

(c) A certain grade of Arkansas bauxite contains 65% Al_2O_3. How many pounds of crystallized potassium alum is it possible to make from 1500 lbs. of this ore?

CHAPTER XIX.

MANGANESE (Mn; 55).

457. **Manganous Compounds.** Treat separate portions of a solution of manganous sulphate ($MnSO_4$) or manganous chloride ($MnCl_2$) with solutions of NaOH, Na_2CO_3 and $(NH_4)_2S$. Does the precipitate formed by NaOH change upon standing? Test the solubility of the $(NH_4)_2S$ precipitate in HCl.

458. Treat a little MnO_2 with concentrated HCl and heat gently. What gas is evolved? Dilute the solution to about twice its volume and filter. To the clear filtrate add NaOH solution.

459. Make a borax bead containing a bit of some manganese compound and heat in the oxidizing and reducing flames. What colors are produced in each flame?

460. **Manganates.** Fuse a little Na_2CO_3 with a mere speck of MnO_2 on a piece of platinum foil. Cool. What color has been produced by the manganese?

This is a very delicate test for manganese.

To 20 cc. of $KMnO_4$ solution in a beaker add NaOH until strongly alkaline. Now add alcohol a drop at a time, stirring constantly, until the solution is green.

What does the solution contain? (See Exp. 461.)

461. **Permanganates.** Treat a small portion of the green solution prepared in the previous experiment with

a little dilute H_2SO_4. Note change in color. Is this due to a chemical or physical change? Explain.

Pass CO_2 through a second portion of the manganate solution from Exp. 460. Explain the change.

462. **Reduction of Permanganates.** To a few cubic centimeters of a dilute $KMnO_4$ solution add a little dilute HCl and then $SnCl_2$ solution. Acidify a second portion of $KMnO_4$ solution with dilute H_2SO_4 and then add SO_2 solution.

In separate test tubes also try the action of H_2S, and alcohol on portions of $KMnO_4$ solution acidified with H_2SO_4.

Why is the $KMnO_4$ solution decolorized in each case? What compounds of manganese are formed when a permanganate is reduced in the presence of an acid? Write all equations involved in this experiment.

463. Treat a little $KMnO_4$ solution with NaOH until strongly alkaline. Now add a few drops of alcohol and agitate. Note the color of the solution. Add a little more alcohol and then warm. Note the change. What is the precipitate?

Compare with the previous experiment. Is the reduction of permanganates in alkaline solution different from that in acid solution? Show by equations the number of oxygen atoms available when $KMnO_4$ oxidizes (1) in acid solution and (2) in alkaline solution.

Examination of Water for Dissolved Oxygen.

(Qualitative.)

464. Completely fill a glass-stoppered bottle with the water to be tested. By means of a pipette or a piece of glass tubing, introduce about 1 cc. of a solution of $MnSO_4$

into the bottle near the bottom. In like manner add 1 cc. of KOH solution. Quickly stopper the bottle and shake to thoroughly mix the contents.

The KOH causes the precipitation of manganous hydroxide ($Mn(OH)_2$) and this, coming in contact with the oxygen dissolved in the water, is oxidized to manganic hydroxide ($Mn(OH)_3$). One atom of oxygen will oxidize two molecules of $Mn(OH)_2$ to $Mn(OH)_3$.

Allow the tightly stoppered bottle to stand about 5 minutes, then remove the stopper and quickly introduce about a cubic centimeter each of KI solution and concentrated HCl, using a pipette or glass tube as before. Quickly stopper the bottle and shake to mix the contents.

The HCl dissolves the $Mn(OH)_3$ and also the excess of $Mn(OH)_2$. With the former, manganic chloride ($MnCl_3$) is formed, but this is not stable; hence it immediately breaks down with formation of $MnCl_2$ and the liberation of chlorine. The chlorine thus liberated reacts with the KI solution, liberating iodine (I) which produces a color varying from yellow to brown, depending upon the amount of oxygen which was dissolved in the water.

One molecule of $Mn(OH)_3$ with HCl liberates one atom of chlorine and this in turn liberates one atom of iodine. Therefore, for every atom of oxygen which was originally contained in solution in the water, two atoms of iodine are liberated. Write equations to represent all chemical changes which take place in this experiment.

This experiment should be tried with several different waters and a statement made as to which contains the most dissolved oxygen. If the various tests show about

the same intensity of color, add a few drops of starch paste to each bottle before drawing conclusions.

Standardization of a Potassium Permanganate Solution and Determination of Iron by Titration.

(Quantitative.)

465. Carefully clean a piece of iron wire by means of sand paper. Accurately weigh out about 0.2 gm. of the clean wire and introduce it into a clean flask. Add a little sodium carbonate to the flask and then about 40 cc. of dilute H_2SO_4. Place a funnel in the flask to serve as a sort of stopper (Fig. 36) and then heat gently until all iron is dissolved.

Obtain a supply (about 50 cc.) of "Standard Permanganate Solution" from the stock bottle. Rinse out a burette with small amounts of this solution and then fill the burette and clamp it in position. (See Fig. 14, page 56.)

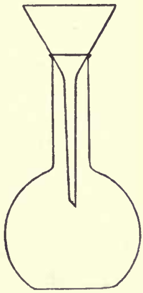


Fig. 36.

Carefully read the level of the solution in the burette. Now remove the funnel from the flask containing the iron solution, and allow permanganate solution to run into the flask a drop at a time, shaking the flask gently after each addition. The titration is complete (all iron is completely oxidized by the permanganate) when a drop of the permanganate solution finally produces a faint pink color. Read the burette accurately. How many cubic centimeters of permanganate solution did it require to oxidize the iron?

Weigh out a second and a third sample of iron wire, dissolve in acid and titrate as before. Compare the results from the three titrations and calculate from each result how much iron each cubic centimeter of the permanganate solution is equivalent to. If the results are fairly close, take the average of the three determinations. This result, expressed as the amount of iron equivalent to 1 cc. of the permanganate solution, is called the iron factor of the solution.

Obtain from the instructor solutions of iron in which you are to determine the exact amount of iron by titration with the "standardized" permanganate solution. The number of cubic centimeters of the permanganate solution required, multiplied by the iron factor of the solution, gives the total amount of iron present.

Summary. How many series of salts has manganese? Which of these are common? Which series is the least common? Give formulas of the oxides of manganese and underline once those distinctly basic in character and underline twice those distinctly acid in character.

What tests could you apply to distinguish between manganese and chromium compounds?

Problems. (a) How many grams of $KMnO_4$ can be reduced by 75 gms. of 90% alcohol (1) in acid solution and (2) in alkaline solution?

(b) How many grams of crystallized ferrous sulphate can be oxidized by 18 gms. of $KMnO_4$ in acid solution?

(c) How many grams of crystallized ammonium manganous sulphate (?) can be prepared from the waste liquor in a chlorine generator in which 680 liters of chlorine have been prepared by the action of MnO_2 with an excess of HCl?

CHAPTER XX.

IRON, COBALT AND NICKEL.

IRON (Fe; 56).

466. Test the solubility of iron in the various mineral acids. Also try the action of fuming nitric acid on iron by dipping a piece of sheet iron into it.

Ferrous Compounds.

467. To separate portions of $FeSO_4$ solution add NH_4OH and $NaOH$. Observe the color of the precipitates; allow to stand for a time and note any change.

468. Try the action of H_2S and of $(NH_4)_2S$ solution on separate portions of $FeSO_4$ solution. Do they react the same? Why?

Test separate portions of $FeSO_4$ solution with solutions of $K_4Fe(CN)_6$, $K_3Fe(CN)_6$ and KCNS. These are good tests; note carefully.

469. To a few cubic centimeters of a solution of $FeSO_4$ add Na_2CO_3 solution. Note the color of the precipitate. Filter rapidly. Test a portion of this precipitate with HCl. Does it effervesce? Is the precipitate a carbonate?

Allow the remainder of the precipitate to stand exposed to the air. Does it change? What is the chemistry of this change?

470. In separate test tubes try the action of $FeSO_4$ solution on solutions of $KMnO_4$ and $K_2Cr_2O_7$ which have been acidified with H_2SO_4. What is the action of $FeSO_4$ in these cases?

471. Fuse a little sulphur with iron filings. Allow to cool. Break the tube and treat the black substance with HCl. Note any odor produced. What is the composition of the black compound?

Treat a little of the mineral "pyrites" (FeS_2) with HCl. Is any odor of H_2S noticeable? Why is there a difference?

472. **Ferrous Sulphate ($FeSO_4$).** Dilute 50 cc. of concentrated H_2SO_4 by pouring it into 250 cc. of distilled water. In a large evaporating dish or casserole, treat 50 gms. of iron filings or nails with the dilute acid. When the action becomes slow, heat the dish gently.

Concentrate the solution by boiling; filter and allow the filtrate to cool and crystallize. Pour off the mother liquor and wash the crystals with a very small amount of water. Dry between filter papers.

Concentrate the mother liquor, add 5 or 10 cc. of strong H_2SO_4 and two or three small pieces of iron and allow to stand for a time to reduce any ferric sulphate to ferrous. Filter concentrate and allow to crystallize.

Ferric Compounds.

473. Prepare a solution of ferric chloride ($FeCl_3$) by dissolving a few grams of iron in aqua regia. Evaporate the solution nearly to dryness; then dilute with 50 cc. of distilled water. Filter if necessary. Use the solution for the ferric tests.

474. To separate portions of $FeCl_3$ solution add NaOH and NH_4OH. Are the precipitates soluble in excess? Are the precipitates the same? Compare with Exp. 467.

Try the action of solutions of the following substances

on separate portions of $FeCl_3$ solution: $K_4Fe(CN)_6$, $K_3Fe(CN)_6$ and KCNS. Make careful note of the precipitates and the colors. Compare with Exp. 468.

475. Treat a solution of $FeCl_3$ with a solution of Na_2CO_3. Is a gas evolved? Can you identify it? Compare the precipitate obtained with that produced by Na_2CO_3 on a ferrous solution (Exp. 469).

476. Pass H_2S through a few cubic centimeters of $FeCl_3$ solution for several minutes. Do you notice any change? Filter; compare the clear filtrate with $FeCl_3$ solution. Are they the same in appearance? Try the action of a solution of $(NH_4)_2S$ on a little $FeCl_3$ solution. Compare with Exp. 468.

477. To a few cubic centimeters of $FeCl_3$ solution in a beaker add Na_2CO_3 solution until nearly neutral. If too much Na_2CO_3 solution is added and the solution is basic to litmus, add dilute HCl, drop by drop, until the solution is barely acid.

To the nearly neutral but slightly acid solution thus prepared add 50 cc. of water and about a gram of $Na(C_2H_3O_2)$ crystals. Heat to boiling; then allow to settle. What is the precipitate? Is it the same as the precipitate formed in Exp. 474?

Filter. Dissolve the precipitate on the filter by adding a few drops of dilute HCl and let the solution run into a clean beaker or test tube. Warm gently and notice the odor.

478. Oxidation of Ferrous Compounds to Ferric. To a few cubic centimeters of $FeSO_4$ solution add a little dilute H_2SO_4 and a drop of concentrated HNO_3. Heat to boiling, cool, and test with KCNS solution.

Repeat, using $KMnO_4$ solution instead of HNO_3. Repeat a second time, using bromine water instead of HNO_3.

479. Ferric Alum. Add 23 cc. of concentrated H_2SO_4 to 60 cc. of distilled water in a large evaporating dish, heat to 100° and add 13 cc. of concentrated HNO_3. Now add 120 gms. of $FeSO_4$ crystals, a little at a time, waiting after each addition until effervescence moderates. When all is dissolved, add concentrated HNO_3, a little at a time, as long as red fumes are evolved. Heat the solution to boiling for a moment and dilute to 300 cc. Filter if necessary.

Heat to boiling, add 40 gms. of $(NH_4)_2SO_4$ and 30 cc. of dilute H_2SO_4. Set aside to crystallize. Dry the crystals between filter papers and preserve in tightly stoppered bottles.

480. Reduction of Ferric Compounds to Ferrous. Reduce a few cubic centimeters of $FeCl_3$ solution by adding $SnCl_2$ solution. Test the resulting solution with KCNS. Also test a portion with $K_3Fe(CN)_6$ solution. (Compare with Exp. 468.) What other reducing agents could be used instead of $SnCl_2$?

Drop a little zinc into a test tube containing $FeCl_3$ solution and add a few drops of concentrated HCl. Allow to stand for a moment. Then test portions for ferrous and ferric salts.

COBALT (Co; 59).

481. To a solution of cobaltous nitrate ($Co(NO_3)_2$) add NaOH until precipitation is complete. Note the color of the precipitate. Now heat to boiling and add

bromine water. Does the precipitate change in color? What two compounds of cobalt have been made in this experiment?

482. Treat separate portions of $Co(NO_3)_2$ solution with solutions of Na_2HPO_4 and Na_2CO_3. Is the precipitate obtained with the latter reagent a carbonate? Test it.

483. Add NaOH to a little $Co(NO_3)_2$ solution until precipitation is complete. Filter and wash the precipitate. Dissolve the precipitate on the paper by adding 3 or 4 cc. of KCN solution and let the solution run into a test tube. Pour the solution through the filter twice. What compound is now in the solution?

Now add a little NaOH and then bromine water. Heat. Explain all changes.

484. Add NH_4OH to a little $Co(NO_3)_2$ solution. What is precipitated? Now add more NH_4OH solution to completely dissolve the precipitate. Pour the solution into a shallow dish and allow to stand exposed to the air.

485. Acidify a few cubic centimeters of $Co(NO_3)_2$ solution and pass H_2S through for a moment. Is a precipitate formed? Now add $(NH_4)_2S$ solution. Does the latter act like H_2S on a cobalt solution?

Filter and wash the precipitate. Test the solubility of a small portion in cold HCl.

486. Make a borax bead and introduce a trace of the precipitate formed in the previous experiment. Try the action of the oxidizing and the reducing flame and note color.

487. To a solution of cobalt chloride ($CoCl_2$) add concentrated HCl. Can you explain the change? Is

it a physical or a chemical change? Now add excess of water.

Carefully evaporate a few cubic centimeters of $CoCl_2$ solution to dryness. Cool and dissolve the residue in a little alcohol. Compare the solution with an aqueous solution.

488. Write on a piece of pink or white paper, using an aqueous solution of $CoCl_2$ instead of ink. Allow the writing to dry. Can you see the writing? Now warm gently by holding at some distance above a Bunsen flame. Explain the change. What use can be made of this property of $CoCl_2$?

489. To a few cubic centimeters of $Co(NO_3)_2$ solution add potassium nitrite (KNO_2) solution and then acetic acid. Allow to stand for a few minutes. Examine the precipitate.

490. To a test tube containing a little water add a drop or two of some cobalt solution and a little KCNS solution. Now add about a half-inch layer of amyl alcohol-ether mixture, shake and examine the color of the amyl alcohol-ether layer. What do you conclude as to the delicacy of this test for cobalt?

NICKEL (Ni; 58).

491. To a solution of nickel nitrate ($Ni(NO_3)_2$) add NaOH. Observe the color of the precipitate. Heat to boiling and add bromine water. Compare with Exp. 481.

492. Try the action of solutions of Na_2CO_3 and Na_2HPO_4 on separate portions of $Ni(NO_3)_2$ solution. Does the Na_2CO_3 precipitate a carbonate? Test it.

493. Precipitate $Ni(OH)_2$ by means of NaOH solu-

tion. Filter and wash; then dissolve the precipitate in KCN solution as in Exp. 483. To the solution add NaOH and bromine water. Heat gently. Compare with Exp. 483.

494. Precipitate NiS by adding $(NH_4)_2S$ solution to any nickel solution. Compare with Exp. 485. Try the solubility of a portion of the precipitate in cold HCl.

495. Make a borax bead, using a bit of the NiS precipitate from the preceding experiment. Heat successively in the oxidizing and reducing flames and note colors produced.

496. To a few drops of any nickel solution in a test tube add a little water and then NH_4OH in excess. Now add a few drops of an alcoholic solution of dimethylglyoxime. Repeat this test with a cobalt solution.

Summary. What is the best test for Fe''? For Fe'''? What is the difference in the action of sodium carbonate solution on ferrous and ferric solutions? How many oxides has iron? What are the chief ores of iron? What is the principle involved in the reduction of iron ores?

Mention several tests by which cobalt and nickel solutions can be distinguished. What is the usual color of nickel compounds? Of cobalt compounds? What nickel compound is a decided exception?

How can nickel and cobalt be distinguished in presence of each other?

Problems. (a) Accurately weigh a United States nickel. How much crystallized nickel ammonium sulphate (?) can be made from this coin? (Is the coin pure nickel?)

(b) What is the percentage composition of crystallized nickel sulphate?

(c) How much 15% solution of KNO_2 will be necessary to precipitate, as potassium cobaltinitrite, all the cobalt in 380 cc. of a 22% solution of cobalt chloride? (Specific gravity of the cobalt solution is 1.122 and of the KNO_2 solution is 1.084.)

(d) To a ladle containing 40 tons of molten steel, a workman adds 450 lbs. of 25% ferro-vanadium and 320 lbs. of 68% ferro-manganese. A chemical analysis of the steel thus produced will show what percentage of vanadium and what percentage of manganese?

CHAPTER XXI.

PLATINUM (Pt; 195)

497. Place what is left of your platinum wire in a test tube and treat it with hot concentrated HCl. Does it dissolve? Wash the wire and successively treat it with H_2SO_4 and HNO_3. What can you say of the solubility of platinum?

Now treat the wire with aqua regia and warm. When it is entirely dissolved, evaporate the solution to small volume and add a cubic centimeter or two of strong NH_4Cl solution. Allow to cool. Filter off the crystals and wash them with a few drops of alcohol. Allow to dry. (Do not throw the filtrate away.)

What is the composition of the crystals? What compound have we heretofore studied which is similar in character?

498. Transfer the dried crystals to a clean porcelain evaporating dish and heat carefully for a time; then ignite strongly. Examine the residue left upon cooling. What is its composition? Dissolve completely in a little aqua regia, evaporate to small volume and then dilute with 20 cc. of water. Use this solution in the following experiments.

499. To a portion of the solution from Exp. 498 add NaOH and grape sugar solutions. Heat to boiling. Allow to stand for a moment. What is the precipitate?

500. Pass H_2S through the remainder of the solution. Filter and wash. Test the solubility of the precipitate in yellow ammonium sulphide. Warm if necessary.

APPENDIX.

CORRECTION OF GAS VOLUMES FOR TEMPERATURE AND PRESSURE CHANGES.

Correction for Temperature Changes.

According to the law of Charles, *the volume of a gas varies directly as the absolute temperature*, provided, of course, that the pressure remains constant. In making corrections for temperature changes, it is necessary, therefore, first to express the temperature as absolute temperature. In practically all scientific work, the centigrade scale of temperature is the one employed.

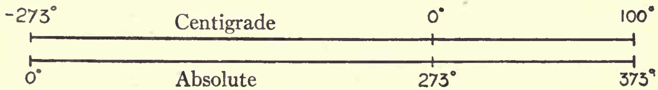


Fig. 37.

On the absolute scale, the degrees are of the same value as the degrees on the centigrade scale, but the absolute zero is 273° below the centigrade 0°. The boiling point on the centigrade scale, 100°, when expressed on the absolute scale will therefore be $100° + 273° = 373°$. The relation between the absolute and centigrade scales can readily be seen from the accompanying drawing (Fig. 37) in which the points on the centigrade scale are directly above the corresponding points on the absolute scale.

To change centigrade into absolute it is necessary simply to add, algebraically, the given centigrade temper-

ature to 273. For example, $30°$ C. expressed on the absolute scale will be the sum of $+30°$ and $+273°$ or $303°$. Likewise, $-17°$ on the centigrade scale when changed to absolute temperature will be found by adding $-17°$ and $+273°$ which gives $256°$.

Once the temperature is expressed on the absolute scale, corrections for temperature changes are simple. If we let

V = given volume,
V' = corrected volume,
T = given temperature (absolute scale),
T' = new temperature (absolute scale),

then, the pressure remaining constant, the corrected volume can be found by the proportion

$$V : V' :: T : T'$$

or

$$V' = \frac{V \times T'}{T}.$$

Example. — *If a gas has a volume of 1200 cc. at 27°, what volume will it occupy at 17°?*

This involves a lowering of the temperature; hence the new volume will be smaller. The temperatures, $27°$ and $17°$, expressed on the absolute scale, are respectively $300°$ and $290°$. Substituting these values in the proportion previously given we have

$$1200 : V' :: 300 : 290$$

or

$$V' = \frac{1200 \times 290}{300} = 1160 \text{ cc.}$$

Correction for Pressure Changes.

According to Boyle's law, if the temperature remains constant, *the volume of a gas varies inversely as the pressure.* In other words, the greater the pressure exerted on a gas the smaller will be the volume. The pressure is measured in millimeters of mercury and the "standard" condition of pressure is the atmospheric pressure at the sea level, which is equal to 760 mm.

In making corrections for pressure changes, let

V = given volume,
V' = corrected volume,
P = given pressure,
P' = new pressure.

According to Boyle's law we have the proportion

$$V : V' :: P' : P$$

and from this

$$V' = \frac{V \times P}{P'}.$$

Example. — *At 750 mm. pressure a gas occupies a volume of 800 cc.; what volume will it occupy at 600 mm. pressure, the temperature remaining constant?*

V = 800 cc.
P = 750 mm.
P' = 600 mm.

The corrected volume, V', will then be found by the proportion

$$800 : V' :: 600 : 750,$$

and from this we have

$$V' = \frac{800 \times 750}{600} = 1000 \text{ cc.}$$

It frequently happens that gas volumes are measured over water, in which case the pressure on the gas is somewhat affected by the pressure of water vapor. This pressure of the water vapor is called the "aqueous tension," and varies with the temperature as shown in Table IV on page 195. In solving problems involving the volume of a gas collected over water, it is therefore necessary to take as the given pressure, not the observed barometric pressure, P, but the barometric pressure minus the aqueous tension at the observed temperature, or $P - a$.

Corrections for Temperature and Pressure Combined.

In correcting for temperature changes we evolved the expression

$$V' = \frac{V \times T'}{T},$$

and in correcting for pressure we likewise evolved a formula

$$V' = \frac{V \times P}{P'}.$$

In applying both corrections at once, we obtain the expression

$$V' = \frac{V \times T' \times P}{T \times P'}.$$

It is advisable to solve problems by such a formula, as many times it will be found possible to cancel, thus greatly lessening the amount of multiplication and division.

Example. — To find the volume which 1800 cc. of a gas at 720 mm. and 47° will occupy if the pressure is

raised to 861 mm. and the temperature is lowered to 14°. Changing the temperature to absolute, and substituting in the formula developed above, we have

$$V' = \frac{1800 \times 287 \times 720}{320 \times 861},$$

which, by cancellation and multiplication, gives

$$V' = 1350 \text{ cc.}$$

Correction to Standard Conditions.

Standard conditions of temperature and pressure are respectively 0° C. and 760 mm.; hence, in correcting gas volumes to standard conditions, $T' = 0°$ C. or 273° absolute, and $P' = 760$ mm. The volume at standard conditions, 0° C. and 760 mm., is usually expressed by V_0.

Example. — *What volume will 210 liters of a gas at 12° and 720 mm. pressure occupy when reduced to standard condition?*

Using the formula heretofore developed,

$$V' = \frac{V \times T' \times P}{T \times P'},$$

or

$$V_0 = \frac{V \times 273 \times P}{T \times 760},$$

we have

$$V_0 = \frac{210 \times 273 \times 720}{285 \times 760},$$

and, by cancellation, we have

$$V_0 = \frac{14 \times 273 \times 18}{19 \times 19} = 190.5 + \text{liters.}$$

CHEMICAL ARITHMETIC.

The importance of chemical arithmetic cannot be overestimated. In general, chemical problems involve only simple mathematical principles, though it frequently happens that several different principles are touched upon in the same problem. To illustrate the solving of chemical mathematical problems, the following type problems have been selected. A careful study of these and the underlying principles will enable the student to negotiate successfully any ordinary problem in chemical mathematics.

I. *What amount of $CaCl_2$ will be produced by dissolving 280 gms. of CaO in HCl?*

The equation for the reaction is

$$CaO + 2\,HCl = CaCl_2 + H_2O.$$

From this we see that from every molecule of CaO, one molecule of $CaCl_2$ is formed. Furthermore the problem deals with CaO and $CaCl_2$ only; hence the other quantities, H_2O and HCl, may be disregarded.

Substituting the sum of the atomic weights under each of the substances involved we have

$$\underbrace{CaO}_{56} + 2\,HCl = \underbrace{CaCl_2}_{110} + H_2O.$$

This shows that for every 56 parts by weight of CaO, there will be produced 110 parts by weight of $CaCl_2$. If 56 parts by weight of CaO produce 110 parts by weight of $CaCl_2$, the amount of $CaCl_2$ in grams that can be produced from 280 gms. of CaO can be found by the proportion

$$56 : 110 :: 280 : x,$$

or

$$x = \frac{110 \times 280}{56} = 550 \text{ gms.}$$

II. *From 2000 pounds of marble, how many pounds of lime can be made?*

Marble is $CaCO_3$; lime is CaO. The equation for the reaction, together with the atomic weights of the substances involved in the problem, is as follows:

$$\underbrace{CaCO_3}_{100} = \underbrace{CaO}_{56} + CO_2.$$

From 100 parts by weight of $CaCO_3$, 56 parts by weight of CaO can be made. The amount that can be made from 2000 pounds of lime can then be found by the proportion

$$100 : 56 :: 2000 : x$$

and

$$x = \frac{56 \times 2000}{100} = 1120 \text{ pounds of lime.}$$

III. (*a*) *From 800 gms. of $CaCO_3$, treated with an excess of acid, how many grams of CO_2 can be made?*

Writing the equation, with the sums of the atomic weights of the substances involved, we have

$$\underbrace{CaCO_3}_{100} + 2\,HCl = CaCl_2 + \underbrace{CO_2}_{44} + H_2O,$$

and from the proportion

$$100 : 44 :: 800 : x,$$

we have

$$x = \frac{44 \times 800}{100},$$

the weight of CO_2 liberated.

(*b*) *What volume would the CO_2 occupy?* In order to find the *volume* of CO_2 it is necessary to find the weight first and then to divide this by the weight of unit volume of the gas. This can be done as follows: CO_2 has a vapor density of 22 (one-half the molecular weight) or, in other words, it is 22 times as heavy as an equal volume of hydrogen. But a liter of hydrogen weighs 0.0899 gm., hence the weight of a liter of CO_2 equals 22×0.0899 gm. By dividing the weight of CO_2 found under part *a*,

$$\frac{44 \times 800}{100},$$

by the weight of a liter of CO_2, we have the expression for V, the volume of the gas in liters,

$$V = \frac{44 \times 800}{100 \times 22 \times 0.0899}.$$

(*c*) *What volume would the CO_2 occupy at 18° and 755 mm. pressure?* The expression developed in *b* represents the volume of CO_2 under standard conditions, 0° C. and 760 mm. pressure, inasmuch as the weight of a liter of hydrogen (0.0899 gm.) under these conditions was used.

To find the volume which the gas would occupy at 18° and 755 mm. it is necessary to find first the volume at 0° and 760 mm. as described above, and then to correct this for the temperature and pressure change. The equation for this correction is

$$V' = \frac{V \times T' \times P}{T \times P'},$$

in which

$$V = \frac{44 \times 800}{100 \times 22 \times 0.0899},$$

$$T = 0° (= 273°),$$
$$T' = 18° (= 291°),$$
$$P = 760 \text{ mm.},$$
$$P' = 755 \text{ mm.}$$

By substituting in the formula above, we have

$$V' = \frac{44 \times 800 \times 291 \times 760}{100 \times 22 \times 0.0899 \times 273 \times 755},$$

which, when solved, gives V', the volume of CO_2 at 18° and 755 mm. which can be obtained from 800 gms. of $CaCO_3$.

IV. *In order to prepare 1250 liters of hydrogen at 12° and 785 mm. pressure, what weight of zinc will be necessary?*

We cannot directly substitute the value, 1250 liters, in a proportion to find weight of zinc, for this would be unduly mixing weight and volume. The weight of the 1250 liters of hydrogen at 12° and 785 mm. must be found first. We know the weight of a liter of hydrogen at 0° and 760 mm. to be 0.0899 gm., but we do not know the weight of a liter of hydrogen at 12° and 785 mm. The volume must, therefore, first be corrected to standard conditions, 0° and 760 mm., before the weight can be found. The formula for this correction is

$$V_0 = \frac{V \times T' \times P}{T \times P'},$$

and, substituting the values, we have

$$V_0 = \frac{1250 \times 273 \times 785}{285 \times 760},$$

which expression gives the volume at 0° and 760 mm. Multiplying this by 0.0899, we find

$$\text{Wt. of H} = \frac{1250 \times 273 \times 785 \times 0.0899}{285 \times 760}.$$

By the equation

$$\underbrace{Zn}_{65} + 2\,HCl = ZnCl_2 + \underbrace{2\,H}_{2}$$

we find that 65 parts by weight of zinc give two parts by weight of hydrogen, and therefore the amount of zinc necessary to produce the weight of hydrogen found above can be ascertained by the proportion

$$65 : 2 :: x : \text{Wt. of H},$$

in which x is the weight of zinc necessary;

$$x = \frac{65 \times \text{Wt. of H}}{2},$$

and substituting the value found for the weight of hydrogen, we have

$$x = \frac{65 \times 1250 \times 273 \times 785 \times 0.0899}{2 \times 285 \times 760},$$

which equals the weight of zinc necessary to produce 1250 liters of hydrogen at 12° and 785 mm. pressure.

V. *What volume of 30% H_2SO_4 (Sp. Gr. 1.222) will be required to dissolve 884 gms. of Fe_2O_3?*

By the equation

$$\underbrace{Fe_2O_3}_{160} + \underbrace{3\,H_2SO_4}_{294} = Fe_2(SO_4)_3 + 3\,H_2O,$$

we find that 160 gms. of Fe_2O_3 require 296 gms. of actual H_2SO_4. Then the amount required to dissolve 884 gms. of Fe_2O_3 can be found by the proportion

$$160 : 294 :: 884 : x,$$

and from this we have

$$x = \frac{294 \times 884}{160}$$

This gives the weight of actual H_2SO_4, but actual H_2SO_4 means 100% H_2SO_4. It will, of course, take considerably more dilute acid than 100% acid. The amount of actual acid, $\frac{294 \times 884}{160}$ gms., is therefore only 30% of the weight of 30% H_2SO_4 needed. This weight may be expressed by multiplying the expression by $\frac{100}{30}$, thus producing the expression

$$\frac{294 \times 884 \times 100}{160 \times 30},$$

which equals the weight of 30% H_2SO_4 necessary.

But the question asks for volume of 30% H_2SO_4 instead of weight. The volume in cubic centimeters is found by dividing the total weight in grams by the weight of 1 cc. of the acid in grams. The question now arises: How much does 1 cc. of 30% H_2SO_4 weigh? But the specific gravity of acid of this strength was given as 1.222. This means that the acid is 1.222 times as heavy as an equal volume of water. But 1 cc. of water weighs 1 gm.; therefore, 1 cc. of 30% H_2SO_4 weighs 1.222 $\times$ 1 gm. or 1.222 gms.

By dividing the expression for grams of 30% H_2SO_4, heretofore developed, by 1.222, we get the volume of the acid in cubic centimeters; thus,

$$\text{Volume in cc.} = \frac{294 \times 884 \times 100}{160 \times 30 \times 1.222}.$$

But if the volume is desired in liters, the expression must be divided by 1000, inasmuch as there are 1000 cc. in a liter.

$$\text{Volume in liters} = \frac{294 \times 884 \times 100}{160 \times 30 \times 1.222 \times 1000}.$$

This, then, gives the volume in liters of 30% H_2SO_4 necessary to dissolve 884 gms. of Fe_2O_3.

VI. The converse of the last problem is equally simple. For example: *What amount of MgO can be dissolved by 4200 cc. of 43% H_2SO_4 (Sp. Gr. = 1.333)?*

The total weight of acid is 4200×1.333 gms., and if the acid is but 43% pure, the total amount of actual H_2SO_4 is

$$\frac{4200 \times 1.333 \times 43}{100} \text{ gms.}$$

By the equation

$$\underbrace{MgO}_{40} + \underbrace{H_2SO_4}_{98} = MgSO_4 + H_2O,$$

we find that 98 parts by weight of actual H_2SO_4 will dissolve just 40 parts by weight of MgO. By using the above expression for weight of actual H_2SO_4 and substituting in the proportion, we have:

$$98 : 40 :: \left(\frac{4200 \times 1.333 \times 43}{100}\right) : x,$$

or

$$x = \frac{4200 \times 1.333 \times 43 \times 40}{98 \times 100}$$

in which x equals the weight of MgO which can be dissolved by 4200 cc. of 43% H_2SO_4.

TABLE I. — APPROXIMATE ATOMIC WEIGHTS.

Aluminum	Al	27	Neodymium	Nd	143
Antimony	Sb	120	Neon	Ne	20
Argon	A	40	Nickel	Ni	58
Arsenic	As	75	Nitrogen	N	14
Barium	Ba	137	Osmium	Os	191
Bismuth	Bi	208	Oxygen	O	16
Boron	B	11	Palladium	Pd	106
Bromine	Br	80	Phosphorus	P	31
Cadmium	Cd	112	Platinum	Pt	195
Caesium	Cs	133	Potassium	K	39
Calcium	Ca	40	Praseodymium	Pr	140
Carbon	C	12	Rhodium	Rh	103
Cerium	Ce	140	Rubidium	Rb	85
Chlorine	Cl	35	Ruthenium	Ru	101
Chromium	Cr	52	Samarium	Sm	150
Cobalt	Co	59	Scandium	Sc	44
Columbium	Cb	93	Selenium	Se	79
Copper	Cu	63	Silicon	Si	28
Erbium	Er	166	Silver	Ag	108
Fluorine	F	19	Sodium	Na	23
Gallium	Ga	70	Strontium	Sr	87
Germanium	Ge	73	Sulphur	S	32
Glucinum	Gl	9	Tantalum	Ta	183
Gold	Au	197	Tellurium	Te	127
Helium	He	4	Terbium	Tb	160
Hydrogen	H	1	Thallium	Tl	204
Indium	In	114	Thorium	Th	232
Iodine	I	127	Thulium	Tu	171
Iridium	Ir	193	Titanium	Ti	48
Iron	Fe	56	Tin	Sn	119
Krypton	Kr	82	Tungsten	W	184
Lanthanum	La	139	Uranium	U	238
Lead	Pb	207	Vanadium	V	51
Lithium	Li	7	Xenon	X	128
Magnesium	Mg	24	Ytterbium	Yb	173
Manganese	Mn	55	Yttrium	Y	89
Mercury	Hg	200	Zinc	Zn	65
Molybdenum	Mo	96	Zirconium	Zr	90

TABLE II.—METRIC WEIGHTS AND MEASURES.

1 meter (m.)	= 100	centimeters (cm.)
	= 1000	millimeters (mm.)
	= 39.37	inches (in.)
	= 1.094	yards (yd.)
1 liter (l.)	= 1000	cubic centimeters (cc.)
	= 33.81	fluid ounces (fl. oz.)
	= 1.057	quarts (qt.)
1 kilogram (kg.)	= 1000	grams (gm.)
	= 35.27	ounces (oz.)
	= 2.205	pounds (lb.)

TABLE III.—SPECIFIC GRAVITY AND MELTING POINT OF THE ELEMENTS.

Element.	Sp. Gr.	M. P.	Element.	Sp. Gr.	M. P.
Aluminum........	2.60	654.5	Magnesium.....	1.74	632.6
Antimony.........	6.62	425–450	Manganese......	7.39	1900
Arsenic...........	5.73	.....	Mercury.........	13.55	−39.38
Barium...........	3.75	85	Molybdenum....	8.6	w. h.
Bismuth..........	9.8	268.3	Nickel..........	8.9	1450
Boron............	2.5	(?)	Osmium.........	22.48	2500
Bromine..........	3.15	−7.3	Palladium......	11.4	1500
Cadmium.........	8.64	316	Phosphorus.....	1.83	44.2
Caesium..........	1.88	26.5	Platinum.......	21.5	1779
Calcium..........	1.58	760	Potassium......	0.87	58
Carbon			Rhodium.......	12.1	2000
(*a*) Diamond ..	3.52	.....	Rubidium.......	1.52	38.5
(*b*) Graphite...	2.3	.....	Ruthenium.....	12.26	1800 (?)
(*c*) Amorphous	1.8	.....	Selenium.......	4.80	217
Cerium...........	6.68	623	Silicon..........	2.39	(?)
Chromium........	6.50	1515	Silver...........	10.50	954
Cobalt...........	8.6	1800	Sodium.........	0.98	95.6
Copper...........	8.93	1054	Strontium......	2.54	(?)
Gallium..........	5.95	30.15	Sulphur		
Germanium......	5.47	900	(*a*) Rhombic..	2.07	114.5
Glucinum........	1.93	900(?)	(*b*) Monoclinic	1.96	120
Gold.............	19.32	1035	Tellurium.......	6.25	452
Indium...........	7.42	176	Thallium.......	11.85	290
Iodine............	4.95	113–5	Titanium.......	3.54	(?)
Iridium..........	22.42	2200	Tin.............	7.29	232.7
Iron..............	7.86	1587	Tungsten.......	19.1	2900 (?)
Lanthanum......	6.1	(?)	Uranium........	18.7	w. h.
Lead.............	11.37	322	Vanadium......	5.5	(?)
Lithium..........	0.59	180	Zinc............	7.1	415.3

TABLE IV. — AQUEOUS TENSION IN MILLIMETERS OF MERCURY.

Temp. C.	Pressure.	Temp. C.	Pressure.
Degrees.		Degrees.	
0	4.6	18	15.4
1	4.9	19	16.4
2	5.3	20	17.4
3	5.7	21	18.5
4	6.1	22	19.7
5	6.5	23	20.9
6	7.0	24	22.2
7	7.5	25	23.5
8	8.0	26	25.0
9	8.6	27	26.5
10	9.2	28	28.1
11	9.8	29	29.8
12	10.5	30	31.6
13	11.2	31	33.4
14	11.9	32	35.4
15	12.8	33	37.4
16	13.6	34	39.6
17	14.4	35	41.9

TABLE V. — TABLE OF HARDNESS.

(On the Scale of 10.)

Agate	7	Iron	4-5
Aluminum	2	Kaolin	1
Antimony	3.3	Lead	1.5
Apatite	5	Lithium	0.6
Arsenic	3.5	Magnesium	2
Barite	3.3	Magnetite	6
Bismuth	2.5	Meerschaum	2-3
Caesium	0.2	Opal	4-6
Calcite	3	Palladium	4.8
Copper	2.5-3	Platinum	4.3
Corundum	9	Potassium	0.5
Diamond	10	Quartz	7
Feldspar	6	Rubidium	0.3
Flint	7	Silver	2.5-3
Fluorite	4	Sodium	0.4
Glass	4.5-6.5	Steel	5-8.5
Gold	2.5-3	Sulphur	1.5-2.5
Graphite	0.5-1	Talc	1
Gypsum	2	Tin	1.8
Halite	2	Topaz	8
Iridium	6	Zinc	2.5

TABLE VI.—SPECIFIC GRAVITY OF H_2SO_4 AT 15° C.

Per Cent Acid.	Sp. Gr.	Per Cent Acid.	Sp. Gr.	Per Cent Acid.	Sp. Gr.
1	1.006	35	1.264	69	1.603
2	1.013	36	1.272	70	1.615
3	1.020	37	1.281	71	1.627
4	1.026	38	1.289	72	1.638
5	1.033	39	1.298	73	1.650
6	1.040	40	1.306	74	1.662
7	1.067	41	1.315	75	1.674
8	1.054	42	1.324	76	1.686
9	1.061	43	1.333	77	1.698
10	1.068	44	1.342	78	1.709
11	1.075	45	1.351	79	1.721
12	1.082	46	1.361	80	1.732
13	1.090	47	1.370	81	1.743
14	1.097	48	1.380	82	1.754
15	1.104	49	1.389	83	1.765
16	1.112	50	1.399	84	1.775
17	1.119	51	1.409	85	1.784
18	1.127	52	1.419	86	1.793
19	1.135	53	1.429	87	1.801
20	1.142	54	1.439	88	1.808
21	1.150	55	1.449	89	1.814
22	1.158	56	1.460	90	1.820
23	1.166	57	1.470	91	1.825
24	1.174	58	1.481	92	1.829
25	1.181	59	1.491	93	1.833
26	1.190	60	1.502	94	1.836
27	1.198	61	1.513	95	1.839
28	1.206	62	1.524	96	1.841
29	1.214	63	1.535	97	1.844
30	1.222	64	1.546	98	1.844
31	1.230	65	1.558	99	1.842
32	1.238	66	1.569	100	1.839
33	1.247	67	1.580		
34	1.255	68	1.592		

TABLE VII. — SPECIFIC GRAVITY OF HCl AT 15° C.

Per Cent Acid.	Sp. Gr.	Per Cent Acid.	Sp. Gr.
1	1.005	21	1.106
2	1.010	22	1.111
3	1.015	23	1.116
4	1.020	24	1.122
5	1.025	25	1.127
6	1.030	26	1.132
7	1.035	27	1.137
8	1.040	28	1.143
9	1.045	29	1.148
10	1.050	30	1.153
11	1.055	31	1.158
12	1.060	32	1.163
13	1.065	33	1.168
14	1.070	34	1.174
15	1.075	35	1.179
16	1.080	36	1.184
17	1.085	37	1.189
18	1.090	38	1.195
19	1.095	39	1.200
20	1.100	40	1.205

TABLE VIII. — SPECIFIC GRAVITY OF H_3PO_4 AT 15° C.

Per Cent Acid.	Sp. Gr.	Per Cent Acid.	Sp. Gr.	Per Cent Acid.	Sp. Gr.
1	1.006	30	1.189	59	1.431
2	1.011	31	1.196	60	1.441
3	1.017	32	1.203	61	1.451
4	1.023	33	1.211	62	1.461
5	1.028	34	1.218	63	1.471
6	1.034	35	1.226	64	1.481
7	1.040	36	1.234	65	1.491
8	1.046	37	1.241	66	1.501
9	1.052	38	1.249	67	1.511
10	1.058	39	1.257	68	1.522
11	1.064	40	1.264	69	1.532
12	1.070	41	1.272	70	1.543
13	1.076	42	1.280	71	1.554
14	1.082	43	1.288	72	1.564
15	1.088	44	1.297	73	1.575
16	1.094	45	1.305	74	1.586
17	1.102	46	1.313	75	1.597
18	1.107	47	1.322	76	1.608
19	1.114	48	1.330	77	1.619
20	1.120	49	1.339	78	1.630
21	1.127	50	1.348	79	1.642
22	1.133	51	1.357	80	1.653
23	1.140	52	1.367	81	1.664
24	1.147	53	1.375	82	1.676
25	1.153	54	1.384	83	1.687
26	1.160	55	1.393	84	1.698
27	1.167	56	1.403	85	1.710
28	1.174	57	1.412		
29	1.182	58	1.421		

TABLE IX. — SPECIFIC GRAVITY OF HNO_3 AT 15 C°.

Per Cent Acid.	Sp. Gr.	Per Cent Acid.	Sp. Gr.	Per Cent Acid.	Sp. Gr.
1	1.006	35	1.219	69	1.418
2	1.011	36	1.226	70	1.423
3	1.017	37	1.233	71	1.427
4	1.023	38	1.239	72	1.431
5	1.028	39	1.246	73	1.435
6	1.034	40	1.253	74	1.439
7	1.039	41	1.259	75	1.443
8	1.045	42	1.266	76	1.447
9	1.051	43	1.272	77	1.450
10	1.057	44	1.279	78	1.454
11	1.063	45	1.285	79	1.458
12	1.069	46	1.292	80	1.462
13	1.075	47	1.298	81	1.465
14	1.081	48	1.304	82	1.469
15	1.088	49	1.311	83	1.472
16	1.094	50	1.317	84	1.475
17	1.100	51	1.323	85	1.479
18	1.107	52	1.329	86	1.481
19	1.113	53	1.335	87	1.485
20	1.120	54	1.341	88	1.487
21	1.126	55	1.347	89	1.490
22	1.133	56	1.353	90	1.493
23	1.139	57	1.358	91	1.495
24	1.148	58	1.364	92	1.498
25	1.152	59	1.369	93	1.500
26	1.159	60	1.375	94	1.502
27	1.165	61	1.380	95	1.504
28	1.172	62	1.385	96	1.506
29	1.179	63	1.390	97	1.508
30	1.185	64	1.395	98	1.511
31	1.192	65	1.400	99	1.516
32	1.199	66	1.405	100	1.525
33	1.206	67	1.409		
34	1.212	68	1.414		

TABLE X. — SOLUBILITY OF THE MORE COMMON SALTS IN WATER AND ACIDS.

1 = soluble in water.
2 = soluble in acids only.
3 = insoluble in water or acids.
1–2 = sparingly soluble in water, readily in acids.
1–3 = sparingly soluble in water and acids.
2–3 = slightly soluble in acids.

	NH_4	Na	K	Ca	Sr	Ba	Mg	Zn	Cd	Hg′	Hg″	Fe″	Fe‴	Al	Cr	Mn	Ni	Co	Pb	Sn″	Sn⁗	Ag	Cu
O	1	1	1	1–2	1	1	2	2	2	2	2	2	2	2–3	2–3	2	2	2	2	2	2–3	2	2
H_2S	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2–3	2	2	2	2	2	2	2	2
HF	1	1	1	2–3	2–3	2–3	2–3	1–2	1–2	...	1–2	1	1–2	1	1	2	1–2	1–2	2	1	1	1	2
HCl	1	1	1	1	1	1	1	1	1	2–3	1	1	1	1	1	1	1	1	1–3	1	1	3	1
HBr	1	1	1	1	1	1	1	1	1	2–3	1	1	1	1	1–3	1	1	1	1–3	...	...	3	1
HI	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1–2	1	1	3	...
HNO_3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	...	1	1
H_2SO_4	1	1	1	1–3	3	3	1	1	1	1–2	1	1	1	1	1	1	1	1	2–3	1	...	1–2	1
H_2CO_3	1	1	1	2	2	2	2	2	2	2	2	2	...	...	...	2	2	2	2	...	...	2	2
H_2SiO_3	...	1	1	2	2	2	2	2	2	...	...	2	2	2–3	2	2	2	2	2	...	...	2	2
H_2CrO_4	1	1	1	1–2	1–2	2	1	1	2	2	1–2	1	...	...	2	1	2	2	2–3	2	...	2	1
$HClO_3$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	...	1	1
H_3PO_4	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
H_3AsO_3	1	1	1	2	2	2	2	...	...	2	2	2	2	...	...	2	2	2	2	...	...	2	2
H_3AsO_4	1	1	1	2	2	2	2	2	...	2	2	2	2	2	2	2	2	2	2	...	2	2	2
H_3BO_3	1	1	1	2	2	2	1–2	2	1–2	...	...	2	2	2	2	2	2	2	2	2	...	2	2
HCN	1	1	1	1	1	1–2	1	2	2	...	1	...	2–3	...	2	2	2–3	2–3	2	...	...	3	2
$H_4Fe(CN)_6$	1	1	1	1	1	1–2	1	2–3	...	...	...	3	3	...	...	2	3	3	2	3	3	3	3
$H_3Fe(CN)_6$	1	1	1	1	...	...	1	2	...	...	...	3	1	...	...	3	3	3	1–2	3	...	3	...
$HC_2H_3O_2$	1	1	1	1	1	1	1	1	1	1–2	1	1	1	1	1	1	1	1	1	1	1	1	1
$H_2C_2O_4$	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1–2	1–2	2	2	2	2	1	2	2
$H_2C_4H_4O_6$	1	1	1	2	2	2	1–2	2	1–2	1–2	2	1	1–2	1	1	1–2	2	1	2	...	2	2	1

TABLE XI.—THE PERIODIC SYSTEM OF THE ELEMENTS.

M°	$M^{I}Cl$ $M_2^{I}O$	$M^{II}Cl_2$ $M^{II}O$	$M^{III}Cl_3$ $M_2^{III}O_3$	$M^{IV}H_4$ $M^{IV}O_2$	$M^{III}H_3$ $M_2^{V}O_5$	$M^{II}H_2$ $M^{VI}O_3$	$M^{I}H$ $M_2^{VII}O_7$	$M^{VIII}O_4$
He=4	Li=7	Gl=9	B=11	C=12	N=14	O=16	F=19	. . . .
Ne=20	Na=23	Mg=24	Al=27	Si=28	P=31	S=32	Cl=35	. . . .
A=40	K=39	Ca=40	Sc=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56 Co=59 Ni=58
. . . .	Cu=63	Zn=65	Ga=70	Ge=73	As=75	Se=79	Br=80	
Kr=82	Rb=85	Sr=87	Y=89	Zr=90	Cl=93	Mo=96	. . .	Ru=101 Rh=103 Pd=106
. . . .	Ag=108	Cd=112.4	In=115	Sn=119	Sb=120	Te=127	I=127	
X=128	Cs=133	Ba=137	La=139	Ce=140	Ta=183	W=184	. . .	Os=191 Ir=193 Pt=195
. . . .	Au=197	Hg=200	Tl=204	Pb=207	Bi=208	. . .	. . .	
. . . .	. . .	Ra=226	. . .	Th=232	. . .	U=238	. . .	. . . .

In this table atomic weights are given in round numbers.

INDEX.

H.

I.

L.

M.

N.

O.

P.

R.

S.

BENNETT, HUGH G. The Manufacture of Leather. 110 illustrations. 8vo. cloth. 438 pp. **net, $4.50**

BERNTHSEN, A. A Text-book of Organic Chemistry. English translation. Edited and revised by J. J. Sudborough. Illus. 12mo. cloth. 690 pp. **net, $2.50**

BERSCH, J. Manufacture of Mineral Lake Pigments. Translated by A. C. Wright. 43 illustrations. 8vo. cloth. 476 pp. **net, $5.00**

BEVERIDGE, JAMES. Papermaker's Pocketbook. Specially compiled for paper mill operatives, engineers, chemists and office officials. *Second and Enlarged Edition.* Illus. 12mo. cloth. 211 pp. **net, $4.00**

BIRCHMORE, W. H. The Interpretation of Gas Analyses. Illustrated. 12mo. cloth. 75 pp. **net, $1.25**

BLÜCHER, H. Modern Industrial Chemistry. Translated by J. P. Millington. Illus. 8vo. cloth. 795 pp. **net, $7.50**

BLYTH, A. W. Foods: Their Composition and Analysis. A manual for the use of analytical chemists, with an introductory essay on the History of Adulterations. *Sixth Edition, thoroughly revised, enlarged and rewritten.* Illustrated. 8vo. cloth. 634 pp. **$7.50**

—— **Poisons: Their Effects and Detection.** A manual for the use of analytical chemists and experts, with an introductory essay on the Growth of Modern Toxicology. *Fourth Edition, revised, enlarged and rewritten.* Illustrated. 8vo. cloth. 772 pp. **$7.50**

BÖCKMANN, F. Celluloid; Its Raw Material, Manufacture, Properties and Uses. 49 illustrations. 12mo. cloth. 120 pp. **net, $2.50**

BOOTH, WILLIAM H. Water Softening and Treatment. 91 illustrations. 8vo. cloth. 310 pp. **net, $2.50**

BOURCART, E. Insecticides, Fungicides, and Weed Killers. Translated by D. Grant. 8vo. cloth. 500 pp. **net, $4.50**

BOURRY, EMILE. A Treatise on Ceramic Industries. A complete manual for pottery, tile, and brick manufacturers. A revised translation from the French by Alfred B. Searle. 308 illustrations. 12 mo. cloth. 488 pp. **net, $5.00**

BRISLEE, F. J. An Introduction to the Study of Fuel. A text-book for those entering the engineering, chemical and technical industries. 60 ill. 8vo. cloth. 293 pp. (Outlines of Industrial Chemistry.) **net, $3.00**

BRUCE, EDWIN M. Detection of the Common Food Adulterants. Illus. 12mo. cloth. 90 pp. **net, $1.25**

BUSKETT, E. W. Fire Assaying. A practical treatise on the fire assaying of gold, silver and lead, including descriptions of the appliances used. Illustrated. 12mo. cloth. 112 pp. **net, $1.25**

BYERS, HORACE G., and KNIGHT, HENRY G. Notes on Qualitative Analysis. 8vo. cloth. 192 pp. **net, $1.50**

CAVEN, R. M., and LANDER, G. D. Systematic Inorganic Chemistry from the Standpoint of the Periodic Law. A text-book for advanced students. Illustrated. 12mo. cloth. 390 pp. **net, $2.00**

CHRISTIE, W. W. Boiler-waters, Scale, Corrosion, Foaming. 77 illustrations. 8vo. cloth. 242 pp. **net, $3.00**

—— **Water, Its Purification and Use in the Industries.** 79 illus., 3 folding plates, 2 colored inserts. 12mo. cloth. 230 pp. **net, $2.00**

CHURCH'S Laboratory Guide. A manual of practical chemistry for colleges and schools, specially arranged for agricultural students. *Ninth Edition, revised and partly rewritten* by Edward Kinch. Illustrated. 8vo. cloth, 365 pp. **net, $2.50**

CORNWALL, H. B. Manual of Blow-pipe Analysis. Qualitative and quantitative. With a complete system of determinative mineralogy. *Sixth Edition, revised.* 70 illustrations. 8vo. cloth. 310 pp. **net, $2.50**

CROSS, C. F., BEVAN, E. J., and SINDALL, R. W. Wood Pulp and Its Uses. With the collaboration of W. N. Bacon. 30 illustrations. 12mo. cloth. 281 pp. (Van Nostrand's Westminster Series.) **net, $2.00**

d'ALBE, E. E. F. Contemporary Chemistry. A survey of the present state, methods, and tendencies of chemical science. 12mo. cloth. 172 pp. **net, $1.25**

DANBY, ARTHUR. Natural Rock Asphalts and Bitumens. Their Geology, History, Properties and Industrial Application. Illustrated. 12mo. cloth. 254 pp. **net, $2.50**

DEERR, N. Cane Sugar. 280 illustrations. 8vo. cloth. 600 pp. **net, $8.00**

DUMESNY, P., and NOYER, J. Wood Products, Distillates and Extracts. Translated by D. Grant. 103 illustrations. 8vo. cloth. 320 pp. **net, $4.50**

DUNSTAN, A. E., and THOLE, F. B. A Text-book of Practical Chemistry for Technical Institutes. 52 illustrations. 12mo. cloth. 345 pp. **net, $1.40**

DYSON, S. S., and CLARKSON, S. S. Chemical Works, Their Design, Erection, and Equipment. 80 illustrations, 9 folding plates. 8vo. cloth. 220 pp. **net, $7.50**

ELIOT, C. W., and STORER, F. H. A Compendious Manual of Qualitative Chemical Analysis. Revised with the co-operation of the authors, by William R. Nichols. *Twenty-second Edition, newly revised* by W. B. Lindsay. Ill. 12mo. cloth. 205 pp. **net, $1.25**

ENNIS, WILLIAM D. Linseed Oil and Other Seed Oils An industrial manual. 88 illustrations. 8vo. cloth 336 pp. **net, $4.00**

ERMEN, W. F. A. The Materials Used in Sizing. Their chemical and physical properties, and simple methods for their technical analysis and valuation. Illustrated. 12mo. cloth. 130 pp. **net, $2.00**

FAY, IRVING W. The Chemistry of the Coal-tar Dyes. 8vo. cloth. 473 pp. **net, $4.00**

FERNBACH, R. L. Chemical Aspects of Silk Manufacture. 12mo. cloth. 84 pp. **net, $1.00**

—— **Glue and Gelatine.** A practical treatise on the methods of testing and use. Illustrated. 8vo. cloth. 208 pp. **net, $3.00**

FISCHER, E. Introduction to the Preparation of Organic Compounds. Translated from the new (eighth) German edition by R. V. Stanford. Illustrated. 12mo. cloth. 194 pp. **net, $1.25**

FOYE, J. C. Chemical Problems. *Fourth Edition, revised and enlarged.* 16mo. cloth. 145 pp. (Van Nostrand Science Series, No. 69.) **$0.50**

FRITSCH, J. The Manufacture of Chemical Manures. Translated from the French, with numerous notes, by Donald Grant. 69 illus., 108 tables. 8vo. cloth. 355 pp. **net, $4.00**

GROSSMANN, J. Ammonia and Its Compounds. Illustrated. 12mo. cloth. 151 pp. **net, $1.25**

HALE, WILLIAM J. Calculations in General Chemistry. With definitions, explanations and problems. *Second Edition, revised.* 12mo. cloth. 185 pp. **net, $1.00**

HALL, CLARE H. Chemistry of Paints and Paint Vehicles. 8vo. cloth. 141 pp. **net, $2.00**

HILDITCH, T. P. A Concise History of Chemistry. 16 diagrams. 12mo. cloth. 273 pp. **net, $1.25**

HOPKINS, N. M. Experimental Electrochemistry: Theoretically and Practically Treated. 132 illustrations. 8vo. cloth. 298 pp. **net, $3.00**

HOULLEVIGUE, L. The Evolution of the Sciences. 8vo. cloth. 377 pp. **net, $2.00**

HÜBNER, JULIUS. Bleaching and Dyeing of Vegetable Fibrous Materials. 95 illus. (many in two colors). 8vo. cloth. 457 pp. (Outlines of Industrial Chemistry.) **net, $5.00**

HUDSON, O. F. Iron and Steel. An introductory text-book for engineers and metallurgists. With a section on Corrosion by Guy D. Bengough. 47 illus. 8vo. cloth. 184 pp. (Outlines of Industrial Chemistry.) **net, $2.00**

HURST, GEO. H. Lubricating Oils, Fats and Greases. Their origin, preparation, properties, uses, and analysis. *Third Edition, revised and enlarged,* by Henry Leask. 74 illus. 8vo. cloth. 405 p. **net, $4.00**

HYDE, FREDERIC S. Solvents, Oils, Gums, Waxes and Allied Substances. $5\frac{1}{4} \times 8\frac{1}{2}$. about 200 pp. In Press.

INGLE, HERBERT. Manual of Agricultural Chemistry. Illustrated. 8vo. cloth. 388 pp. **net, $3.00**

JOHNSTON, J. F. W. Elements of Agricultural Chemistry. Revised and rewritten by Charles A. Cameron and C. M. Aikman. *Nineteenth Edition.* Illustrated. 12mo. cloth. 502 pp. **$2.60**

JONES, HARRY C. A New Era in Chemistry. Some of the more important developments in general chemistry during the last quarter of a century. Illustrated. 12mo. cloth. 336 pp. **net, $2.00**

KEMBLE, W. F., and UNDERHILL, C. R. The Periodic Law and the Hydrogen Spectrum. Illustrated. 8vo. paper. 16 pp. **net, $0.50**

KERSHAW, J. B. C. Fuel, Water, and Gas Analysis, for Steam Users. 50 ill. 8vo. cloth. 178 pp. **net, $2.50**

KNOX, JOSEPH. Physico-chemical Calculations. 12mo. cloth. 196 pp. **net, $1.00**

KOLLER, T. Cosmetics. A handbook of the manufacture, employment and testing of all cosmetic materials and cosmetic specialties. Translated from the German by Charles Salter. 8vo. cloth. 262 pp. **net, $2.50**

KREMANN, R. The Application of Physico-chemical Theory to Technical Processes and Manufacturing Methods. Authorized translation by Harold E. Potts, M.Sc. 35 diagrams. 8vo. cloth. 215 pp. In Press.

KRETSCHMAR, KARL. Yarn and Warp Sizing in All Its Branches. Translated from the German by C. Salter. 122 illus. 8vo. cloth. 192 pp. **net, $4.00**

LAMBORN, L. L. Modern Soaps, Candles and Glycerin. 224 illustrations. 8vo. cloth. 700 pp. **net, $7.50**

—— **Cotton Seed Products.** 79 illus. 8vo. cloth. 253 pp. **net, $3.00**

LASSAR-COHN. Introduction to Modern Scientific Chemistry. In the form of popular lectures suited for University Extension students and general readers. Translated from the *Second German Edition* by M. M. Pattison Muir. Illus. 12mo. cloth. 356 pp. **$2.00**

LETTS, E. A. Some Fundamental Problems in Chemistry: Old and New. 44 illustrations. 8vo. cloth. 236 pp. In Press.

LUNGE, GEORGE. Technical Methods of Chemical Analysis. Translated from the *Second German Edition* by Charles A. Keane, with the collaboration of eminent experts. To be complete in three volumes.

Vol. I. (in two parts). 201 illustrations. 8vo. cloth. 1024 pp. **net, $15 00**

Vol. II. (in two parts). Illus. 6¼ x 9. 1294 pp. **net, $18.00**

Vol. III. in active preparation.

—— **Technical Chemists' Handbook.** Tables and meth-

ods of analysis for manufacturers of inorganic chemical products. Illus. 12mo. leather. 276 pp. **net, $3.50**

—— **Coal, Tar and Ammonia.** *Fourth and Enlarged Edition.* In two volumes, not sold separately. 305 illustrations. 8vo. cloth. 1210 pp. **net, $15.00**

—— **The Manufacture of Sulphuric Acid and Alkali.** A theoretical and practical treatise.

Vol. I. Sulphuric Acid. *Fourth Edition, enlarged.* In three parts, not sold separately. 543 illustrations. 8vo. cloth. 1665 pp. **net, $18.00**

Vol. II. Sulphate of Soda, Hydrochloric Acid, Leblanc Soda. *Third Edition, much enlarged.* In two parts, not sold separately. 335 illustrations. 8vo. cloth. 1044 pp. **net, $15.00**

Vol. III. Ammonia Soda. Various Processes of Alkali-making, and the Chlorine Industry. 181 illustrations. 8vo. cloth. 784 pp. **net, $10.00**

Vol. IV. Electrolytical Methods. In Press.

McINTOSH, JOHN G. The Manufacture of Varnish and Kindred Industries. Illus. 8vo. cloth. In 3 volumes.
Vol. I. Oil Crushing, Refining and Boiling; Manufacture of Linoleum; Printing and Lithographic Inks; India Rubber Substitutes. 29 illus. 160 pp. **net, $3.50**
Vol. II. Varnish Materials and Oil Varnish Making. 66 illus. 216 pp. **net, $4.00**
Vol. III. Spirit Varnishes and Varnish Materials. 64 illus. 492 pp. **net, $4.50**

MARTIN, G. Triumphs and Wonders of Modern Chemistry. A popular treatise on modern chemistry and its marvels written in non-technical language. 76 illustrations. 12mo. cloth. 358 pp. **net, $2.00**

MELICK, CHARLES W. Dairy Laboratory Guide. 52 illustrations. 12mo. cloth. 135 pp. **net, $1.25**

MERCK, E. Chemical Reagents: Their Purity and Tests. 8vo. cloth. 250 pp. New Edition in Press.

MITCHELL, C. A. Mineral and Aerated Waters. 111 illustrations. 8vo. cloth. 244 pp. **net, $3.00**

MITCHELL, C. A., and PRIDEAUX, R. M. Fibres Used in Textile and Allied Industries. 66 illustrations. 8vo. cloth. 208 pp. **net, $3.00**

MUNBY, A. E. Introduction to the Chemistry and Physics of Building Materials. Illus. 8vo. cloth. 365 pp. (Van Nostrand's Westminster Series.) **net, $2.00**

MURRAY, J. A. Soils and Manures. 33 illustrations. 8vo. cloth. 367 pp. (Van Nostrand's Westminster Series.) **net, $2.00**

NAQUET, A. Legal Chemistry. A guide to the detection of poisons as applied to chemical jurisprudence. Translated, with additions, from the French, by J. P. Battershall. *Second Edition, revised with additions.* 12mo. cloth. 190 pp. **$2.00**

NEAVE, G. B., and HEILBRON, I. M. The Identification of Organic Compounds. 12mo. cloth. 111 pp. **net, $1.25**

NORTH, H. B. Laboratory Notes of Experiments in General Chemistry. Illus. 12mo. cloth. **net, $1.00**

OLSEN, J. C. A Textbook of Quantitative Chemical Analysis by Gravimetric and Gasometric Methods. Including 74 laboratory exercises giving the analysis of pure salts, alloys, minerals and technical products. *Fourth Edition. revised and enlarged.* 74 illustrations. 8vo. cloth., 576 pp. **net, $4.00**

PAKES, W. C. G., and NANKIVELL, A. T. The Science of Hygiene. A text-book of laboratory practice. 80 illustrations. 12mo. cloth. 175 pp. **net, $1.75**

PARRY, ERNEST J. The Chemistry of Essential Oils and Artificial Perfumes. *Second Edition, thoroughly revised and greatly enlarged.* Illustrated. 8vo. cloth. 554 pp. **net, $5.00**

—— **Food and Drugs.** In 2 volumes. Illus. 8vo. cloth. Vol. I. The Analysis of Food and Drugs (Chemical and Microscopical). 59 illus. 724 pp. **net, $7.50**
Vol. II. The Sale of Food and Drugs Acts, 1873-1907. 184 pp. **net, $3.00**

PARTINGTON, JAMES R. A Text-book of Thermodynamics (with special reference to Chemistry). 91 diagrams. 8vo. cloth. 550 pp. In Press.

—— **Higher Mathematics for Chemical Students.** 44 diagrams. 12mo. cloth. 272 pp. **net, $2.00**

PERKIN, F. M. Practical Methods of Inorganic Chemistry. Illustrated. 12mo. cloth. 152 pp. **net, $1.00**

PHILLIPS, J. Engineering Chemistry. A practical treatise. Comprising methods of analysis and valuation of the principal materials used in engineering works. *Third Edition, revised and enlarged.* Illustrated. 12mo. cloth. 422 pp. **net, $4.50**

PLATTNER'S Manual of Qualitative and Quantitative Analysis with the Blowpipe. *Eighth Edition, revised.* Translated by Henry B. Cornwall, assisted by John H. Caswell, from the *Sixth German Edition*, by Friedrich Kolbeck. 87 ill. 8vo. cloth. 463 pp. **net, $4.00**

POLLEYN, F. Dressings and Finishings for Textile Fabrics and Their Application. Translated from the *Third German Edition* by Chas. Salter. 60 illustrations. 8vo. cloth. 279 pp. **net, $3.00**

POPE, F. G. Modern Research in Organic Chemistry. 261 diagrams. 12mo. cloth. 336 pp. **net, $2.25**

POTTS, HAROLD E. Chemistry of the Rubber Industry. 8vo. cloth. 163 pp. (Outlines of Industrial Chemistry.) **net, $2.00**

PRESCOTT, A. B. Organic Analysis. A manual of the descriptive and analytical chemistry of certain carbon compounds in common use. *Sixth Edition.* Illustrated. 8vo. cloth. 533 pp. **$5.00**

PRESCOTT, A. B., and JOHNSON, O. C. Qualitative Chemical Analysis. *Sixth Edition, revised and enlarged.* 8vo. cloth. 439 pp. **net, $3.50**

PRESCOTT, A. B., and SULLIVAN, E. C. First Book in Qualitative Chemistry. For studies of water solution and mass action. *Eleventh Edition, entirely rewritten.* 12mo. cloth. 150 pp. **net, $1.50**

PRIDEAUX, E. B. R. Problems in Physical Chemistry with Practical Applications. 13 diagrams. 8vo. cloth. 323 pp. **net, $2.00**

PROST, E. Manual of Chemical Analysis. As applied to the assay of fuels, ores, metals, alloys, salts, and other mineral products. Translated from the original by J. C. Smith. Illus. 8vo. cloth. 300 pp. **net, $4.50**

PYNCHON, T. R. Introduction to Chemical Physics. *Third Edition, revised and enlarged.* 269 illustrations. 8vo. cloth. 575 pp. **$3.00**

RICHARDS, W. A., and NORTH, H. B. A Manual of Cement Testing. For the use of engineers and chemists in colleges and in the field. 56 illustrations. 12mo. cloth. 147 pp. **net, $1.50**

ROGERS, ALLEN. A Laboratory Guide of Industrial Chemistry. Illustrated. 8vo. cloth. 170 pp. **net, $1.50**

ROGERS, ALLEN, and AUBERT, ALFRED B. (Editors.) **Industrial Chemistry.** A manual for the student and manufacturer. Written by a staff of eminent specialists. 340 illus. 8vo. cloth. 872 pp. **net, $5.00**

ROHLAND, PAUL. The Colloidal and Crystalloidal State of Matter. Translated by W. J. Britland and H. E. Potts. 12mo. cloth. 54 pp. **net, $1.25**

ROTH, W. A. Exercises in Physical Chemistry. Authorized translation by A. T. Cameron. 49 illustrations. 8vo. cloth. 208 pp. **net, $2.00**

SCHERER, R. Casein: Its Preparation and Technical Utilization. Translated from the German by Charles Salter. *Second Edition, revised and enlarged.* Illustrated. 8vo. cloth. 196 pp. **net, $3.00**

SCHIDROWITZ, P. Rubber. Its Production and Industrial Uses. Plates, 83 illus. 8vo. cloth. 320 pp. **net, $5.00**

SCHWEIZER, V. Distillation of Resins, Resinate Lakes and Pigments. Illustrated. 8vo. cloth. 183 pp. **net, $3.50**

SCOTT, W. W. Qualitative Chemical Analysis. A laboratory manual. *Second Edition, thoroughly revised.* Illus. 8vo. cloth. 180 pp. **net, $1.50**

SEARLE, ALFRED B. Modern Brickmaking. 260 illustrations. 8vo. cloth. 449 pp. **net, $5.00**

SEIDELL, A. Solubilities of Inorganic and Organic Substances. A handbook of the most reliable quantitative solubility determinations. *Second Printing, corrected.* 8vo. cloth. 367 pp. **net, $3.00**

SENTER, G. Outlines of Physical Chemistry. *Second Edition, revised.* Illus. 12mo. cloth. 401 pp. **$1.75**

—— **A Text-book of Inorganic Chemistry.** 90 illustrations. 12mo. cloth. 595 pp. **net, $1.75**

SEXTON, A. H. Fuel and Refractory Materials. *Second Ed., revised.* 104 illus. 12mo. cloth. 374 pp. **net, $2.00**

—— **Chemistry of the Materials of Engineering.** Illus. 12mo. cloth. 344 pp. **net, $2.50**

SIMMONS, W. H., and MITCHELL, C. A. Edible Fats and Oils. Their composition, manufacture and analysis. Illustrated. 8vo. cloth. 164 pp. **net, $3.00**

SINDALL, R. W. The Manufacture of Paper. 58 illus. 8vo. cloth. 285 pp . (Van Nostrand's Westminster Series.) **net, $2.00**

SINDALL, R. W., and BACON, W. N. The Testing of Wood Pulp. A practical handbook for the pulp and paper trades. Illus. 8vo. cloth. 150 pp. **net, $2.50**

SMITH, W. The Chemistry of Hat Manufacturing. Revised and edited by Albert Shonk. Illustrated. 12mo. cloth. 132 pp. **net, $3.00**

SOUTHCOMBE, J. E. Chemistry of the Oil Industries. Illus. 8vo. cloth. 209 pp. (Outlines of Industrial Chemistry.) **net, $3.00**

SPEYERS, C. L. Text-book of Physical Chemistry. 20 illustrations. 8vo. cloth. 230 pp. **net, $2.25**

STEVENS, H. P. Paper Mill Chemist. 67 illustrations. 82 tables. 16mo. cloth. 280 pp. **net, $2.50**

SUDBOROUGH, J. J., and JAMES, J. C. Practical Organic Chemistry. 92 illustrations. 12mo. cloth. 394 pp. **net, $2.00**

TERRY, H. L. India Rubber and Its Manufacture. 18 illustrations. 8vo. cloth. 303 pp. (Van Nostrand's Westminster Series.) **net, $2.00**

TITHERLEY, A. W. Laboratory Course of Organic Chemistry, Including Qualitative Organic Analysis. Illustrated. 8vo. cloth. 235 pp. **net, $2.00**

TOCH, M. Chemistry and Technology of Mixed Paints. 62 photo-micrographs and engravings. 8vo. cloth. 166 pp. **net, $3.00**

TOCH, M. Materials for Permanent Painting. A manual for manufacturers, art dealers, artists, and collectors. With full-page plates. Illustrated. 12mo. cloth. 208 pp. **net, $2.00**

TUCKER, J. H. A Manual of Sugar Analysis. *Sixth Edition.* 43 illustrations. 8vo. cloth. 353 pp. **$3.50**

VAN NOSTRAND'S Chemical Annual, Based on Biedermann's "Chemiker Kalender." Edited by J. C. Olsen, with the co-operation of eminent chemists. *Third Issue,* 1913. 12mo. cloth. **net, $2.50**

VINCENT, C. Ammonia and Its Compounds. Their manufacture and uses. Translated from the French by M. J. Salter. 32 ill. 8vo. cloth. 113 pp. **net, $2.00**

VON GEORGIEVICS, G. Chemical Technology of Textile Fibres. Translated from the German by Charles Salter. 47 illustrations. 8vo. cloth. 320 pp. **net, $4.50**

—— **Chemistry of Dyestuffs.** Translated from the *Second German Edition* by Charles Salter. 8vo. cloth. 412 pp. **net, $4.50**

WADMORE, J. M. Elementary Chemical Theory. Illus. 12mo. cloth. 286 pp. **net, $1.50**

WANKLYN, J. A. Milk Analysis. A practical treatise on the examination of milk and its derivatives, cream, butter and cheese. Illus. 12mo. cloth. 73 pp. **$1.00**

—— **Water Analysis.** A practical treatise on the examination of potable water. *Eleventh Edition, revised,* by W. J. Cooper. Illus. 12mo. cloth. 213 pp. **$2.00**

WILSON, F. J., and HEILBRON, I. M. Chemical Theory and Calculations. An elementary text-book. Illus., 3 folding plates. 12mo. cloth. 145 pp. **net, $1.00**

WINKLER, C., and LUNGE, G. Handbook of Technical Gas Analysis. *Second English Edition.* Illustrated. 8vo. cloth. 190 pp. **$4.00**

WORDEN, E. C. The Nitrocellulose Industry. A compendium of the history, chemistry, manufacture, commercial application, and analysis of nitrates, acetates, and xanthates of cellulose as applied to the peaceful arts. With a chapter on gun cotton, smokeless powder and explosive cellulose nitrates. Illustrated. 8vo. cloth. Two volumes. 1239 pp. **net, $10.00**

—— **Cellulose Acetate.** A monograph of the history, chemistry, manufacture, technical applications and analysis of the non-explosive esters of cellulose and starch. Illus. 12mo. cloth. In Press.

Any book in this list sent postpaid anywhere in the world on receipt of price.

D. VAN NOSTRAND COMPANY

Publishers and Booksellers

25 PARK PLACE NEW YORK

5 M—8—11—13